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Development and Classification of Archaeos (Pleospongia)

By

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Development and Classification of Archaeos (Pleospongia)

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We attempt in the present paper to base a natural classification of the Archaeos on the character of the earliest known stages of development of their skeleton.

These stages, or "spitzes," are at present best known is etched siliceous material from the Ajax Mine, South Australia. In attempting to correlate these forms with overseas species of which details of development are not yet known, we realise that such correlation is necessarily provisional; but, as a very large amount of work will have to be done before a complete and satisfactory classification can be expected, a provisional scheme may be serviceable if only by calling attention to the need for further developmental studies.

In the present paper descriptions are given of the following new orders, families, genera, and species:

Family Rhizacyathidae.
Genus Rhizacyathus.
Species Acanthinocyathus transiens.
Order Ajacicyathina.
Family Alphacyathidae.
Genus Alphacyathus.
Species Alphacyathus zero.
Family Ajacicyathidae.
Genus Ajacicyathus.
Family Sigmocoscinidae.
Species Archaeopharetra vologdini.
Family Flindersicyathidae.
Order Crommyocyathina.
Family Exocyathidae.

Order *MONOCYANTHINA* (Okulitch).

Single-walled, slightly tapering, porous tubes. They appear to be the most primitive adult sponges and resemble the *Olynthus* stage of sponges. The largest species (*porosus*) has very numerous uniform pores, regularly arranged in quincunx, the wall being almost identical with the outer wall of such an Archaeo as *Dokidocyathus*. The smallest species (*irregularis*) has irregularly scattered circular pores, most of which are on little papillae. Another species (*spinosus*) has a wall of regular more open reticular texture with tubercles projecting outwards from the nodes.

Family *MONOCYATHIDAE* (Bedford).

This, with characters as above, is the typical family. Vologdin (Problems of Palaeontology, Moscow, 1937) places *Monocyathus* with *Rhabdocyathus sibiricus* (von Toll) in a family *Rhabdocyathidae*, considering these two forms as alike in structure. We cannot agree with this. Von Toll's description of *Rhabdocyathus* is as follows (Memoires de L'Academic Imperiale des Sci. de St. Petersbourg, 1899): "The case consists of a cylindrical or subcylindrical rod-shaped cup, whose walls are formed of thin calcareous lamellae. In the lower part of the cup these lamellae are numerous and arranged concentrically; as they are separated by a space they form an inner and an outer wall of the cup. Stout little tubes go out from the inner wall, traverse the outer wall, and form by their exit the outer pores. Some of the little tubes grow out beyond the outer wall, whereby in the transverse section their lumina are visible as excentric openings beside the outer wall. In the upper part of the Rhabdocyathus cup inner and outer walls lie close together, but in transverse sections outer and particularly inner walls show as thicker lamellae, which contrasts as strongly refracting layers with the middle parts of the cup-wall which are formed of fine but compacted lamellae. The pores are arranged in regular rows."

Von Toll, in another passage, refers to "the inner wall, formed by simple infolding" and says "pores traverse the closely opposed walls."

Von Toll regarded *Rhabdocyathus* as a primitive,

gastrula-like form, with two walls which are close together above, more widely separated below; he regarded *Archaeocyathus* and *Spirocyathus* as developed from this stage by widening of the intervallum and the appearance of septa. Neither in von Toll's description of *Rhabdocyathus* nor in his interpretation of it as an infolded gastrula is there any resemblance whatever to *Monocyathus*. Von Toll's figures show two walls in the lower part, the outer wall being greatly thickened by concentric excrescences, and an intervallum of considerable width between the walls, the intervallum being traversed by little tubes. Double walls, intervallum and excrescences are all alike absent in *Monocyathus*. In an accompanying diagram the wall-pores are shown regularly arranged "in quadra"; this is quite different from the condition in *Monocyathus*, in which the wall-pores when regularly arranged are invariably "in quincunx."

No doubt forms of *Monocyathus* have been or will be found in Siberia, but, if so, they cannot reasonably be referred to the quite different *Rhabdocyathus* as described by von Toll.

Spitzes of Monocyathus.

Monocyathus irregularis. One of the smallest *Monocyathus* spitzes seen diminishes, in a length of 7 mm., from 1½ mm. at the upper end to ½ mm. at the lower. It is figured in Plate XLII, Fig. 160. Though apparently broken at the lower end this is evidently very close to the extreme tip, and it indicates that the individual originates as a delicate irregular conical tube, probably closed at the tip as a little hemispherical cup of ¼ mm. or less in diameter, for this seems to be the normal termination of the best preserved small Archaeo spitzes. Pores may be absent from the first 1 mm. or 2 mm., and become scattered and fairly numerous as the distance from the tip increases. The pores in this species are in the main circular, irregular in size and distribution, and as a rule each pore occupies the summit of a little pimple or papilla. As will be seen later, such a simple conical tube, with or without pores at first, is the starting point in the growth of many, if not all, of the more highly organised regular Archaeos, in the young spitzes of which also the "papilliporous" condition is often noticeable.

Archaeo Spitzes in general.

As regards Archaeos in general we may say here that, though we have looked carefully, we have never yet seen in the Ajax Mine material any earlier larval stage than the single-walled conical tube; we have traced the best preserved of many Archaeo spitzes down to hemispherical terminations of varying sizes, such as ¼ and 1/5 mm., and in one case 1/10 mm.

Vologdin says (loc cit.) that a study of Siberian material shows the Archaeo larvae to have been floating "spawn-like, nearly skeleton-less organisms, 1/100 mm. in diameter." These grew and "acquired a thin calcareous spheroidal hollow coating (the sphaerion stage) which is sometimes preserved in a fossil state," and reached a size of 1/10 to 1/5 mm. They became slightly elongated "gradually forming inside a second wall" (the dolium stage). With growth of the "dolium" and increase in the weight of the skeleton, the organism settled to the bottom and passed to the fixed life; growing upwards, the larva gradually developed into a conical calyx. "Stability on the substratum was achieved by a subsequent growth of the base by means of additional skeletal elements or, in addition to this, by a filling of all the hollows of the lower part of the calyx with a calcareous skeletal mass."

Our material has so far given no representation of a "sphaerion" stage, and, as regards a "dolium" stage, it shows on the contrary quite clearly that the inner wall actually arises within the developing conical single-walled spitz at a time when the latter has attained a diameter usually of ½ to ¾ mm. Okulitch (Trans. Roy. Soc. of Canada, 1935) figures serial transverse sections of small spitzes of regular Archaeos. He says "It is clear that the inner wall *does not* make its appearance simultaneously with the outer wall and the septa, but is a subsequent development." He also points out that Taylor's previously published sections (Memoirs of Roy. Soc. of S. Aus., 1910) are not typical, being made on material in which exothecal tissue and secondary silicification obscured the position. We agree in nearly all points with Okulitch.

As regards the basal fixation referred to by Vologdin, the great majority of specimens from the Ajax Mine have no such indication, the spitzes being quite naked without structural means of attachment. There appears to be diversity in this respect in different Archaeo localities, and where, as in some localities, exothecal or "root" structures are prevalent, we have a suspicion that these are parasitic or encrusting organisms specifically distinct from the enclosed Archaeo. Considerable reference to this matter was made in our fourth memoir and we shall come to it again later.

Several groups of Archaeos may well have evolved from an ancestral type corresponding to *Monocyathus irregularis*. A regularisation of the pores would give rise to *Monocyathus porosus*, and this, combined with the appearance of an inner wall and connecting rods would lead first to *Dictyocyathus*-like forms and next, by concentration of the rods in longitudinal rows, to the regular Archaeos, and further, by concentration both longitudinally and transversely, to *Coscinocyathus* and its relatives. Another line of evolution from the *Monocyathus irregularis* type, commencing with the appearance of imperforate transverse partitions in the tube and continuing with growth of trabeculae from these partitions and from the wall would lead to the various forms of the Order *Metacyathina*.

Spitz of Monocyathus porosus, Bedford.

The smallest spitz of *Monocyathus porosus* so far found is shown on Plate XLII, Fig. 161. Unfortunately this is still 2 mm. diameter at the smaller end, so that we are unable yet to say whether the regular arrangement of numerous pores in quincunx continues to the extreme tip. The absence of smaller spitzes of this form suggests a possibility that some of the specimens attributed to *M. irregularis* may be spitzes of *M. porosus*, but of course, until a specimen of *M. porosus* is found complete in its lower part, we have no direct evidence on this point. The most interesting feature of *Monocyathus porosus* (see our earlier figures, particularly Plate X, Fig. 46) is its strong resemblance to the outer wall of several of the regular Archaeos.

Spitz of Monocyathus spinosus, Bedford.

The spitz previously figured in Plate X, Fig. 50, was the first fragment found of this very scarce species; we have since found another fragment (Plate XLII, Fig. 162) which well shows the very regular structure of the upper part. The construction is quite different from that of *M. irregularis*, for it consists of a regular trabecular mesh which encloses relatively large polygonal pores and has spines or tubercles projecting outwards. Whereas *M. irregularis* is at first essentially a continuous tube, *M. spinosus* has from the first a wall which is openly reticular. In this respect it may be perhaps regarded as the single walled prototype of the Acanthinocyathina. *Monocyathus mellifer* is a scarce but well defined species; the wall is beautifully regular, the pores forming a honeycomb pattern; its structure is thus intermediate between that of *M. porosus* and *M. spinosus*.

Note on the Order *Monocyathina*.

Taylor, in his 1910 memoir, noticed fragments of these, saying "the shape reminds one of the primitive *Olynthus* of the sponges" and "it is possible that these organisms are mature sponges whose development has not proceeded further than the *Olynthus* stage." Taylor does not relate these forms to the Archaeos; he speaks of them as sponges, whilst he is inclined to regard the Archaeos as primitive "Cambrian Metazoa" intermediate between sponges and corals; he says "it is suggested that . . . in the Archaeocyathinae we have evidence of the modifications of the generalised type which gave rise to the Calcarea and Anthozoa."

In 1934 we described two species *Monocyathus porosus* and *M. irregularis*, and related them to the Archaeos as members of a new family Monocyathidae. Okulitch in 1935 gave this family ordinal rank as Monocyathina. He placed the whole of the Archaeos in an independent class of the Porifera, and at first called this class Cyathospongia, but, finding the name preoccupied, changed it later to Pleospongia; Monocyathina being the most primitive order of the class and being regarded as representing the ancestral type of the more complex forms. Okulitch's view of the general position of the Archaeos appears to be gaining more acceptance than any previously put forward.

Tunkia incerta, Bedford.

This very small organism is described in our third memoir (Sept. 1936). Although there is considerable resemblance to *Monocyathus*, we hesitate to class it with that group on account of the different state of preservation. A photograph of this organism appears in a paper of March, 1937 (Neuen Jahrb. fur Mineralogic) by T. H. Ting, who worked on material from the Ajax Mine sent by us in exchange to Dr. Krantz, of Bonn. Ting refers the specimen, as *Calathium sp*, to the genus described by Billings in 1865. Billings considered his *Calathium* as related to *Archaeocyathus* and was inclined at first to regard both as protozoa and later (Pal. fossils I. p. 357) as sponges. The identity of *Tunkia* with *Calathium* is extremely improbable; 2 mm. is large for the diameter of *Tunkia* and $\frac{1}{4}$ mm. for the pores, the wall being 1/5 mm. thick; whereas the *Calathium* specimens Ting refers to are from 20 mm. to 60 mm. diameter and the pores 2 mm. diameter, the wall being up to 12 mm. thick. The extreme difference between the two genera may be at once realised by inspecting Billing's figure of another species, *Calathium anstedi* (or *crassum*) (1 c. p. 337); we shall have occasion to refer to this figure later.

Family *Archaeophyllidae*, Vologdin.

Vologdin in 1931 described some conical or cornute cups, up to about 10 mm. diameter, characterised by a single wall with external as well as internal vertical ribs. He spoke of the wall as non-porous, but qualified this in 1937 by saying "one sometimes shows a porous structure." The cavity is traversed by numerous horizontal plates, slightly concave upwards; he spoke of these as tabulae and as continuous and thin near the wall, and passing in places into a sort of vesicular tissue. He described two genera, *Archaeophyllum* (with 2 species) and *Butovia*. We give in Fig. 164 trans. and long. sections of *Archaeophyllum* sketched roughly from Vologdin's figures.

It may be of interest to compare this single walled, non-porous type, having transverse partitions, with the "Archaeopharetra" spitz of Metacyathina.

New Family *Rhizacyathidae* and genus *Rhizacyathus*.

In our last memoir we described a little cylindrical form, *Protopharetra radix;* this has outer wall, but no inner wall or central cavity, the interior being occupied by anastomosing bars which have in the main a sloping longitudinal orientation. Transverse sections of a spitz of similar character are shown in Plate XLII, Fig. 165. This has the structure neither of a regular Archaeo spitz nor of a transversely partitioned Metacythine spitz, and

we propose the new generic name *Rhizacyathus,* with *Rhizacyathus radix* as genotype. The form may perhaps be regarded as one modified from *Monocyathus.*

Family *Rhabdocyathidae,* Vologdin.

The family includes three genera of relatively simple construction, viz., *Rhabdocyathus* Toll, *Rhabdocyathella* Vologdin, and *Yakovlevia* Vologdin. We give in Plate XLII, Fig. 163, a rough sketch of *Yakovlevia,* in transverse section, after one of Vologdin's figures.

Summary of Order *MONOCYATHINA.*

Family *Monocyathidae,* Bedford.

All the species known so far have been described by us from the Ajax Mine. They fall into three groups, but we await further knowledge before distinguishing them generically.

First group; tube at first continuous, later with scattered pores: *Monocyathus irregularis.*

Second group; tube with regular pores in quincunx: *M. porosus* (the genotype), *M. robustus, M. sparsipora.*

Third group; tube-wall reticular: *M. spinosus, M. Mellifer* (? 2nd or 3rd group).

Of doubtful affinity: *Tunkia incerta.*

Family *Archaeophyllidae,* Vologdin, Genera, Archaeophyllum and Butovia, Vologdin.

Family *Rhizacyathidae,* Bedford. Genus Rhizacyathus, Bedford.

Family *Rhabdocyathidae,* Vologdin. Genera Rhabdocyathus, Toll; Rhabdocyathella and Yakovlevia, Vologdin.

Order *ACANTHINOCYATHINA,* Okulitch.

The order was established by Okulitch, 1935, on the family Acanthinocyathidae, Bedford, 1934.

The names Acanthocyathus, etc., first given were found to be preoccupied, and Acanthinocyathus, etc., were substituted.

The specimens agree with normal Archaeos in the possession of two walls; these are united by a very scanty framework of delicate radial rods. The inner wall is a very open simple polygonal net. The outer wall is built up, as it were, of a series of fused spicular elements enclosing large open spaces; spines or tubercles often project outwards beyond the general wall surface. The spitz, so far as known, has the same open net-like structure.

Spitz of Acanthinocyathus.

The smallest spitz found of this group is illustrated in Plate XLII, Fig. 166. It is a fragment 9 mm. long, 3 mm. diameter at the upper and 1 mm. at the lower end. The fragment is well preserved; it shows the outer wall as a loose open net along the whole length of the specimen; the characteristic inner wall is actually seen down to a point within about 3 mm. of the tip, from which point downwards the inner wall is shaved away in the specimen, but, from the presence of radial rods, the existence of the inner wall to within a mm. or so of the tip can be inferred; the two walls are connected, as in the adult, by sparsely scattered delicate radial rods.

The simplicity of structure, open texture, and continuity of character down nearly to the end of the spitz, together with the absence at all points of anything in the nature of a sheet-like structure perforated by pores, form a combination of qualities which separate this from all other groups of the Archaeos, and suggest a line of evolution from some such single-walled form as *Monocyathus spinosus.*

? *Acanthinocyathus transiens,* sp. nov.

In Plate XLII, Fig. 167, is illustrated a fragment from the Ajax Mine, which, whilst differing from previously described species, has points of resemblance to *Acanthinocyathus.* It is too fragmentary for complete description, but the outer wall is of an irregular network type, and delicate, more or less radial, sparsely distributed rods proceed inwards from the mesh. These rods, however, appear occasionally to anastomose, which is never the case in *A. apertus.* The specimen is too fragmentary to make it clear whether a defined inner wall (as in *Acanthinocyathus*) is present.

Summary of Order *Acanthinocyathina.*

The species so far described are all from the Ajax Mine; they comprise:

Acanthinocyathus apertus.
? *Acanthinocyathus transiens* sp. nov.
Pinacocyathus spicularis.

New Order *AJACICYATHINA.*

Examination of a number of spitzes of various species shows that members of that large group of Archaeos which includes not only the most regular and characteristic forms with porous outer and inner walls and straight porous plate-like septa, but also numerous forms with rod-like bars in the intervallum, originate in a spitz of a certain well-defined type, as described below. All the members of this group may be considered as forming a natural order.

The nomenclature of the group has come to present considerable difficulty. Taking first those typical Archaeos with straight septa which are developed from such a spitz, and finding, as we have done, that *not all* Archaeos with straight septa develop from such a spitz, what generic name is to be applied to those typical Archaeos?

In recent years most workers have drifted into the

habit of naming the most characteristic members of the group "Archaeocyathus," but Gordon in 1920 (Trans. Roy. Soc. Edinburgh) and Okulitch in 1937 (Journal of Palaeontology) have both pointed out that this is not permissible. Gordon held *Archaeocyathus profundus*, Billings (1865), to be the type species of *Archaeocyathus;* but Okulitch shows clearly that *Archaeocyathus atlanticus*, Billings (1861), is actually the type species. The position now becomes rather complicated. Gordon, holding *profundus* to be the type species, says, "It is impossible to group the present forms known as *Archaeocyathus* under Billings' original (i.e. *atlanticus*) or amended (i.e. *profundus*) definition." Gordon's reason for this is, we take it, the presence of dissepiments in *A. profundus*. Gordon then proceeds to erect a new genus for the regular forms, which he calls *Thalamocyathus*, but he gives no genotype; the first species he mentions is *tubavallum*, Taylor, a very unlucky choice, because it is founded on a single abnormally preserved fragment and is about the only one of Taylor's numerous species of which confirmation is lacking; besides this Taylor's two figures of *tubavallum* are mutually contradictory; his figure 28 shows the inner view of the inner wall with 2 or 3 rows of regular pore-pipes to the intersept, rather as in his description, whilst figure 29 shows an irregular wall, somewhat resembling *retezona*. The second species he mentions is *trachealis*, Taylor, a perfectly good and plentiful species, but not of the simple generic type we are considering, of which type it is a specialised development, which would now be put in a separate family.

(Gordon's photograph of his fossil which he refers to *A. tubavallum* is very close to *A. retezona* (Taylor).)

Okulitch (l.c.), rightly considering *A. atlanticus* as the genotype of *Archaeocyathus*, and dropping the genus *Spirocyathus* as invalid, because it was founded by Hinde (1889) on *Archaeocyathus atlanticus*, and is therefore an exact synonym of *Archaeocyathus*, proposed a new genus *Cambrocyathus* "to include *Archaeocyathus profundus* and its congeners." The question now arises as to the interpretation of "congeners," which, by implication, Okulitch appears to take as including the regular Archaeos we are now discussing; he says also, "Cambrocyathidae to be used instead of Archaeocyathidae (as used by Hinde, Bornemann, Taylor, Vologdin, Bedford, and Okulitch)." This, however, is not, we think, practicable, because *Archaeocyathus profundus* (Billings, 1935), whatever it is, is not a member of the group we are discussing; it is a very large form, more than a foot in length with a diameter of two to four inches; the external surface has strong circular ridges, about $\frac{1}{2}$ inch apart and $\frac{1}{4}$ inch deep, and Billings' figure shows synapticulae or dissepiments between the septa. It is clear that *Cambrocyathus* (Okulitch) with its genotype *profundus* (Billings) is not the type we are now looking for; on the contrary it has some resemblance to *Pycnoidocyathus*, Taylor, but we have not sufficient data to relate it definitely to any group with which we are acquainted.

The only other genotypes for consideration are the following:—

Ethmophyllum whitneyi, Meek (1868).

The genus, as originally described by Meek, has an outer wall "beautifully punctuate, the punctures being minute, of exactly uniform size, and arranged with mathematical regularity in quincunx, and so closely crowded that . . . ." Septa straight near outer wall, becoming regularly waved further in. Two rows of alternating canals within each interseptal space at the inner wall. "These canals . . . do not pass *directly* through the inner wall, but are directed obliquely upward and inward, so that as seen in transverse sections . . . they present the appearance of a double row of vesicles cut across."

Meek says apparently two species were present, the larger one, *E. whitneyi*, being the type. He makes no mention of the character of the inner wall and septa and leaves it to us to guess if he meant the generic description to apply. The smaller species "differs from the other in having its septa so strongly waved laterally as almost to divide the interseptal spaces into cells, nearly to the outer wall"; this he calls *Ethmophyllum gracile*.

Meek gives no illustrations, and a few months later abandoned the genus in favor of *Archaeocyathus*.

Walcott resuscitated the genus in 1866 and gave it a much wider extension, to include *whitneyi, minganense, profundum, rensselaericum, rarum*. He also published several figures of *whitneyi*, some said to be from types. Three widely different Archaeos appear in these figures, and in none of them do the septa and inner wall correspond with Meek's description.

Hinde in 1889 (Q.J.G.S.) redefined the genus on the lines of Meek's original generic description.

We must accept oblique canals opening inwards and upwards into the central cavity as an essential feature of the inner wall of *Ethmophyllum;* it cannot, therefore, serve as the type of the group under consideration.

Archaeocyathellus ? *rensselaericus*, Ford, 1873.

This appears to be the first tentative suggestion of a generic name for what appears to be a small regular Archaeo. Ford, however, does not seem to have confirmed the name; he said, "Should a further study of it confirm this opinion, I propose to call it *Archaeocyathellus*. Until, however, more can be said about it, I prefer to class it as above" (by "as above," apparently "as *Archaeocyathus*" is meant). Ford's specimen had slender dissepiments; it was fluted externally like *A. floreus*. The name *Archaeocyathellus* does not appear to have been definitely adopted even by

Ford; and has not since been resuscitated. Walcott used for it the generic name *Ethmophyllum* and subsequent writers *Archaeocyathus*. Seeing that *rensselaericus* is not completely defined in respect of anatomy and development and that it may have had dissepiments, it would not now be one's choice as genotype if the choice were open, and Ford's hesitancy leaves the choice open; it therefore seems inadvisable to resuscitate the genus unless for fluted species of a certain kind.

Protocyathus rarus, Ford, 1878, is another small, fluted form. It has a specialised outer wall, with a single row of stirrup pores at the line of each septum. The generic name has since been abandoned, but might be resuscitated usefully for species having this particular character.

Taking all these names into consideration, it appears that up to the present no unequivocal generic name or genotype has been proposed for the most characteristic forms of regular Archaeos having straight septa, uniformly porous and simple outer and inner walls, devoid of synapticulae or dissepiments usually of regular conical shape, without flutings, and growing from a simple normal spitz. Such an Archaeo is *Archaeocyathus ajax*, Taylor; this species has also the practical advantage of being so plentiful and well-preserved that all points in its anatomy and growth can be elucidated and duplicates can readily be procured for distribution and comparison.

We therefore propose the generic name *Ajacicyathus* for these forms, with *Ajacicyathus ajax*, Taylor, as genotype, and to adapt the same name in the correspondingly family and order, as *Ajacicyathidae* and *Ajacicythina* respectively. The order is based on the character of the spitz and therefore includes not only many of the forms lately called "Archaeocyathus" but also some *Dictocyathus*, *Dokidocyathus*, and other forms.

The definition of the order *Ajacicyathina* is:— Regular Pleospongia growing from a spitz in the form of a simple conical tube, closed below, within which arises almost immediately a porous inner wall connected to the tube by radial rods. The tube becomes perforated to form a porous outer wall; the radial rods develop in some cases into a trabecular mesh, in others into regular radial usually porous "septa" and/or transverse "tabulae."

Family *Alphacyathidae*. New Family.

Genus *Alphacyathus*. New Genus.

Growing from the same kind of spitz as *Ajacicyathus* are a number of species which do not develop straight radial septa, but retain in the adult what appears to be the primitive condition, viz., a scaffolding of rods uniting the two walls. By far the simplest and most minute form of the kind we have seen is a single specimen described below as *Alphacyathus zero;* we prefer, however, to make *Alphacyathus anularis* the genotype, as a fair number of specimens of this have been found.

Alphacyathus zero. New Species.

The single specimen found is figured in Plate XLIII, Fig. 168. Its extreme minuteness is shown by the fact that, although apparently a mature individual and not a mere spitz, its diameter at the upper end is only $1\frac{1}{4}$ mm., with an intervallum distance of about $\frac{1}{4}$ mm. The length is about 6 mm. The extreme tip is not seen, but is so near that the diameter at the lower end is only $\frac{1}{2}$ mm. The inner wall has minute pores, about 8 to the mm., regularly arranged in quincunx. The outer wall pores are not seen. The two walls are connected by numerous simple rather irregular radial rods.

Alphacyathus anularis (Genotype).
(*Dictyocyathus anularis*, Bedford.)

The species is described in our second paper, see Plate XI, Fig. 55, and will serve, for the reasons just given, as genotype. An excellent specimen has now been found, complete to the tip of the spitz, and is shown in Plate XLIII, Fig. 169. This shows that the skeleton commences as a simple conical tube, closed at the lower end by a hemispherical cap. At $\frac{1}{2}$ mm. diameter (b) radial rods are beginning to grow inwards from the wall and at 2/3 mm. diameter (c) the inner wall appears, and outer and inner wall-pores. For the most part the connections between the walls in the adult are simple radial rods, but there is a tendency for these to be united by a single tangential row of synapticulae to form incomplete horizontal platforms, a kind of forerunner of the tabulae of *Coscinocyathus*. This feature is specific and not essential to the genus, which may be defined as simple, regular Pleospongia consisting of inner and outer regularly porous walls united by radial rods, circular in section, usually numerous and isolated but occasionally united by a single row of tangential synapticulae, growing from a simple spitz of similar character. A spitz of this type will be here referred to for convenience as a "spitz of Alphacyathus type."

In the same genus is placed *Alphacyathus simplex* (=*Dictyocyathus simplex* Taylor), and *Alphacyathus robustus* (= *Dictyocyathus robustus* Bedford). *Dictyocyathus macdonelli* Bedford may be included here provisionally, though it is a larger form and of a more expanding conical shape, and, being founded on a single, obscurely preserved fragment in which wall pores are not seen, it is insufficiently known for precise determination.

Genus *Dictyocyathus* Bornemann.

Bornemann defined the genus as follows: Cup with fine-pored outer wall and sieve-like inner wall pierced

with larger pores. The interval between outer and inner wall without continuous septa and walls only connected by a very delicate scaffolding of cylindrical bars. Referring to Bornemann's only species, the genotype, *Dictyocyathus tenerrimus*, he says the cup is beaker-shaped, the spitz running into a cone. The rods of the scaffolding appear in cross section as round or oval points, in longitudinal section as more or less broken lines.

Bornemann gives very sketchy drawings of a fragmentary specimen, the clearest of which is copied roughly here in Plate XLIII, Fig. 170. There is nothing inconsistent in his description and sketches with its being a member of the family we now have under consideration. From the presence in the genotype of what appear to be anastomising rods in the intervallum, and of a conical spitz, the generic name may be used to include other species having these characters.

Dictyocyathus graphicus.

(*Protopharetra graphica* Bedford)

Spitzes of this species are shown in Plate XLIII, Fig. 171, 172, 173. This spitz is of "Alphacyathus type," but the simple radial bars in the intervallum soon give place to a mesh with vertical and tangential as well as radial members. As there is reason to believe that there are other Pleospongia with a somewhat similar intervallar mesh in the adult, which do not grow from a spitz of "Alphacyathus type," and therefore would not be included in the present order, it is difficult to place adult fragments of which the spitz is not available. It would thus be important to determine whether any characters can be found in the adult which might serve to distinguish such specimens. To clear up this point will require further research, so that any suggestions which can be made at present are only tentative.

For example, regular and regularly arranged pores in outer and inner walls are in favor of this family as against irregular reticular and compound-reticular, i.e., spongy walls. Also, simple pores to the inner walls as against large canals leading inwards and upwards into the central cavity. Again where the intervallar elements join the outer wall they are often seen in tangential section to have an arrangement "in quadra." See, for example, Fig. 173, upper part of sketch, also Plate XII, Fig. 58D and 60B; this may, perhaps, be a useful distinction. The presence or absence of a circularly striated pellis "plastered" (as it were) outside the outer wall is a confusing feature; it is seldom if ever found on the most regular archaeos (*Ajacicyathus*, etc.) and is common in the lower part of Metacyathina (e.g., Plate XXX, Figs. 120C, 123A); on the other hand, it occurs on some *Dictyocyathus* forms (e.g., Plate XII, Figs. 58D, 60B). Its occurrence as a localised coat associated with (?) "*Exocyathus*" lamellae on a specimen of *Metacoscinus* (Plate XXXIV, Fig. 134) is here suggestive of a parasitic or pathological condition; but, if so, it seems to have a preference for distinct though often widely-separated species. To this genus belong also apparently *Dictyocyathus irregularis* Taylor, *robustus* and *quadruplex* Bedford.

Genus *Spirillicyathus* Bedford.

These small forms, which appear to grow from a spitz of Alphacyathus type, present features intermediate between *Dictyocyathus* and the regular septate forms, having partial and rudimentary septa; the outer wall is more irregular than is usual in members of this order. (See our fourth memoir, p. 30). The small unidentified spitz shown in Plate XLIV, Fig. 174, in successive sections from 7/8 mm. to 5/16 mm. diameter, resembles this type.

Genus *Dokidocyathus* Taylor.

The genotype *Dokidocyathus simplicissimus* Taylor is a large, relatively common, very well-known and clearly defined type. The scattered simple rods connecting inner and outer walls are not circular, as in *Alphacyathus*, but extended longitudinally, forming, so to speak, very short widely spaced septa. Spitzes of this species are of the Alphacyathus type and are shown on Plate XLIV, Figs. 175, 176, 177.

Another species, almost devoid of septal bars, is *Dokidocyathus nihilum* Bedford.

New Family *Ajacicyathidae.*

For reasons which have been given above we propose this family for the inclusion of the most characteristic group of regular septate archaeos, growing from a spitz of Alphacyathus type—the group which has come to be spoken of in recent years as *Archaeocyathus*—a name which, it has been shown, cannot be used for them. From this family we exclude, in particular, such related forms as *trachealis* with a highly specialised inner wall. The presence of either synapticulae or dissepiments as a normal feature of any species appears to indicate its exclusion from this and closely related families (though the possibility may have to be considered of dissepiments occurring abnormally as a result of fracture and repair even in species of this family).

New Genus *Ajacicyathus.*

The genotype *Ajacicyathus ajax* (*Archaeocyathus ajax* Taylor) is fully described by Taylor. Outer wall delicate with extremely fine pores distributed regularly about 6 to the mm. Septa regularly arranged and numerous, with pores rather remote and small, irregular rows of six or seven occurring in an intervallum. Inner wall rather solid with regularly arranged pores, 3 to the mm.; some being "stirrup pores," others not.

As regards characters which might be considered when now or later the family comes to be subdivided into more numerous genera, the following may be sug-

gested as features of close relationship to the genotype: pores of both walls regularly and closely arranged in quincunx; the inner wall with stirrup pores at the line of each septum and with further rows of pores in each intersept; outer surface without vertical flutings. The presence of a coarser net supporting the inner wall, as in *retezona*, does not indicate more than specific difference, because we find hybrid forms grading between this species and *ajax*.

On the other hand, features suggestive of generic difference are fluting of the outer surface, arrangement of outer wall-pores in isolated rows instead of in regular quincunx, absence of stirrup-pores in inner wall, and presence of projections from the inner wall into the central cavity (other than irregular tissue in the central cavity near base, which may perhaps be an occasional senescent feature).

Spitz of Ajacicyathus ajax, etc.

The spitz, as of all members of the family, appears to be of Alphacyathus type; it is therefore for purpose of exact identification necessary to find it attached to a greater or less length of the cup in which adult specific features are developed, and this is seldom possible, as the spitzes are usually broken off; one is therefore often compelled to compare notes between a poorly preserved attached spitz and a well preserved detached one.

Our results agree very closely with those of Okulitch described in his 1935 paper. He says, "An Archaeocyathid starts growing as a simple, perforate cup," with which we agree: but when he says, "The pores are of about the same size as in the adults," we may say that in our specimens there is a tendency for the pores of the lowest part to be obscured or irregularly scattered and to be smaller than in the adult. He then says, "After a while a single septum appears. It may disappear and reappear again in the same or another position in the cup or grow uninterruptedly." This description is not really inconsistent with ours, viz., that the septal structure commences typically as radial bars rather than vertically extended "septa." Okulitch further says, "It is clear that the inner wall does not make its appearance simultaneously with the outer wall and the septa, but is a subsequent development, depending on the growth of septa"; our results confirm this, but as regards his statement, "The inner wall is not cup shaped, as heretofore supposed, but is a hollow tube or truncate cone open at both ends," we are not quite sure on this point, as a few of our specimens appear to indicate a closure or plugging at the lower end. These, however, are minor points, and as already stated, our results agree very closely with Okulitch's. Our most complete specimens measure from 1/10 to 1/4 mm. diameter just above the hemispherical cap and Okulitch says his were "seldom exceeding ½ mm." so that we were working with material of about the same dimensions.

We have not noticed any particular persistence of a stage of 1, 2, 4, 6 or any other defined number of vertical rows of septal bars, and have no reason to suppose that these follow any other plan than indefinite increase in pace with the expansion of the cup, which applies also to the septa formed from these bars.

Taylor gives sections and descriptions of young stages of archaeos, but his material did not show stages under 1 mm. diameter, being mostly from the less favorable occurrence at Sellick's Hill.

Our results yield no confirmation of Ting's description (l.c., p. 346/7) of the first septum and inner wall as arising by invagination from the outer wall.

A number of etched sections of young spitzes from various points of view are shown in Plate XLIV, Fig. 178, and in Plate XLV.

By far the commonest archaeos at the Ajax Mine are *Ajacicyathus ajax* and *retezona* and *Cyclocyathus trachealis* and the majority of spitzes may fairly be presumed to belong to these forms, but as distinctive specific features do not seem to appear till a diameter above about 2 mm., it is very difficult to be certain of the specific identification of the smallest spitzes.

In Plate XLIV, Fig. 178, is shown an instructive small spitz of Ajax-retezona type; at (A) is the surface as first exposed, the papilliporous condition of the pores there shown is often seen in small specimens of a few mm. diameter and often seems to be lost in older ones. The exposed transverse sections above and below are shown in B, which is 1⅛ mm. diameter and shows four septal bars and both porous walls, and in C, which is 1/3 mm. diameter and shows a single porous tube. The specimen was then ground off longitudinally and re-etched, D, to graze the inner wall; and the process repeated, E, to show a median section, with the inner view of inner wall exposed. The specimen shows that the spitz originates as a simple conical porous tube, septal bars and porous inner wall being added when the diameter has increased to about 2/3 mm.

In Plate XLV, Fig. 179, is shown a series of transverse sections of a similar spitz ending below in a hemispherical cup 1/5 mm. diameter; rods appear at 1/3 mm., and the inner wall at ½ mm.

In Plate XLV, Fig. 180, is shown a very small spitz. At A is shown the appearance when first exposed, and at B and C the result of further grinding away of matrix. The fragment is broken off and somewhat crushed above, D being an oblique transverse section produced by grinding off a little more of the specimen to a diameter of ¾ mm. Further longitudinal grinding and etching gave Figs. E and F. The tip of this little specimen is the smallest complete one we have found, measuring only 1/10 mm. just above the tip; from this it continues as a single conical tube, irregularly porous, until at under ½ mm. rods and inner wall appear. The rods develop rapidly into septa, which are well established at ¾ mm.

Three sections of a small spitz, looked at from below, are shown in Plate XLV, Fig. 181. At A the commencement of the inner wall appears to be closed below, and two septal rods are seen, the tube here being 7/16 mm. diameter.

Plate XLV, Fig. 182, shows, at a diameter between $\frac{7}{8}$ mm. and $1\frac{1}{2}$ mm., transition from septal rods to septa in a spitz of *ajax-retezona* type.

Plate XLV, Fig. 183, shows transverse, and three successive oblique longitudinal sections of 1 mm. spitz.

Species at the Ajax Mine closely related to *Ajacicyathus ajax* are *Ajacicyathus retezona* (Taylor's *Archaeocyathus retezona*), *Ajacicyathus stapipora* (Taylor's *Archaeocyathus stapipora*) and *Ajacicyathus aequitriens, endothecalis* and *brunhilda* Bedford. Other species, but without any stirrup pores in the inner wall, are *Ajacicyathus subacutus, aequisemis, carmen* and *divaricatus* Bedford.

Other South Australian genera of this family are *Cadniacyathus* Bedford and *Zonacyathus* Bedford.

Family *Bronchocyathidae* Bedford.

Archaeos growing from a spitz of Alphacyathus type and developing a specialised inner wall in which circular shelves or bars are the main feature. The outer wall is of normal, finely porous type.

The first and best known species of this family was described by Taylor in 1910 as *Archaeocyathus trachealis*. Vologdin in 1931 described three similar species from Siberia, giving them the new generic name *Cyclocyathus*. By the way, Vologdin, in calling attention to the similarity, accidentally confused two specific names in the paper by Gordon, and referred to and copied a photograph as *tubavallum* when evidently *trachealis* was intended. Vologdin did not specify a genotype, but, if he is agreeable, we would suggest *trachealis* as being much the most completely known species. In the meantime we had given the new name *Bronchocyathus* to this and other forms, being misled at a first reading of Vologdin's paper, by the identification of his genus with *tubavallum*, which we now see was a mere lapsus calami on his part. We are therefore adopting Vologdin's generic name for the forms near *trachealis* and wish to retain our name *Bronchocyathus* for those with a more complex inner wall like Taylor's *Ethmophyllum dentatum*, and the family name *Bronchocyathidae* for both of these as well as other related genera.

Genus *Cyclocyathus*, Vologdin.

There is a single circular shelf corresponding to each horizontal row of pores in the inner wall. *Cyclocyathus trachealis* (Taylor's *Archaeocyathus trachealis*) is the first described and best known form, being one of the commonest species at the Ajax Mine.

Several small spitzes have been examined by us. One, clearly identified from the upper part as *Cyclocyathus trachealis*, is shown in a series of transverse sections in Plate XLV, Fig. 184. This spitz is of *Alphacyathus* type and is traced down to a diameter of 5/16 mm. where rods are appearing, whilst at about $\frac{3}{8}$ mm. the inner wall is indicated. Fig. 185 is a longitudinal section of another small spitz 2/3 to 1/3 mm. diameter which is probably also *trachealis*. Transverse sections of another *trachealis* spitz at a higher level are shown (on a smaller scale) in Fig. 186; at 1 mm. diameter septa are well established and, between $1\frac{1}{2}$ and 2 mm., the characteristic shelves of the inner wall show as anular thickenings. An identified unsilicified fragment is shown in median longitudinal section in Fig. 187; at the diameter sketched, 1 mm., the septa have a more open reticular texture than is apparent in the silicified specimens. The spitz of 3 mm. to $1\frac{3}{4}$ mm. diameter shown in Fig. 184 explains clearly the origin of the circular shelves; at $1\frac{3}{4}$ mm. the inner wall pores are still in quincunx, with no sign of shelves; shortly above this diameter little inward projections appear above each pore, and soon unite as wavy horizontal lines; between this and the 3 mm. stage the pores rapidly lose their quincunx arrangement and the wavy shelves straighten out, so that at 3 mm. diameter the characteristic adult form is developed, the wall pores being in regular quadrate arrangement—one horizontal row of pores between each pair of shelves and one vertical row in each intersept.

T. H. Ting gave in 1937 (l.c., p. 347) an entirely different description of the development of *trachealis*, showing the septa as all arising successively by invagination from the outer wall and the shelves arising de novo as rings joining the inner ends of the septa, without any intervening stage of a porous inner wall. The material we have worked on is quite definite and gives no confirmation of Ting's description.

Cyclocyathus trachealis is a widely distributed species, having been found by Gordon in Antarctica, and Vologdin describes three other species from Siberia. *Cyclocyathus sigmoideus* (*Bronchocyathus sigmoideus* Bedford) is another species from the Ajax Mine. We have found an unusual type of tabular structure to occur sporadically in *Cyclocyathus*, and Taylor's *"Coscinocyathus" anlax* is almost certainly a member of this genus and not a *Coscinocyathus*.

Genus *Bronchocyathus* Bedford.

We wish to retain this generic name for members of the family having large spinous and other structures projecting into the central cavity and superimposed on a system of circular shelves. *Bronchocyathus dentatus* (Taylor's *Ethmophyllum dentatum*), which will become the genotype, is clearly to be derived from a *trachealis*-like form by further extension of the shelf material into the central cavity. *Bronchocyathus tracheodentatus* Bedford is a similar form.

Vologdin's species *Ethmophyllum karangani* and *caveaquadratum* may be members of or near this family.

Genus *Ethmocyathus*, Bedford.

Ethmocyathus lineatus, the genotype and only species so far found, differs considerably from such genera as *Cyclocyathus*, as it has three or four minute horizontal rings running across each pore of the inner wall.

Family *Tercyathidae* Vologdin.

The two genera of this family are described by Vologdin as follows:

Genus *Tercyathus* Vologdin.

The external wall is costate, reticulate; the internal wall has a spongy structure and is thickened to the size of the intervallum.

Genus *Clathricyathus* Vologdin.

The external wall is porous and of a reticulate structure, while the internal wall is highly complicated, after the type of genus *Ethmophyllum*.

In Fig. 189 we give a transverse section of *Tercyathus altaicus* roughly sketched after a figure of Vologdin's. These genera appear to be related to the Bronchocyathidae.

Family *Coscinocyathidae*, Taylor.

Clear small spitzes of Coscinocyathus are difficult to find in the Ajax Mine material, as secondary silicification often masks the outer wall pores and the internal detail. One of the best fragments of a small spitz we have found is shown in Plate XLVI, Fig. 190. The transverse section, A, as first exposed at a diameter of 1½ mm. showed a tabula, and this was apparently the first to be formed, as, when the wall was ground away to show the internal structure in longitudinal section, b, no lower tabulae were indicated. The lowest part of the fragment, at 2/3 mm. diameter, seems to have a typical "Alphacyathus spitz" structure, with septal rods beginning to give place to septa. Outer wall pores are obscured. Fig. 191 shows a spitz from 2-2/3 mm. diameter above to 1½ mm. below; outer wall pores are visible at the upper left hand, obscured below. Fig. 192 shows longitudinal and transverse sections of a spitz from 3½ mm. to 1½ mm. diameter. In both the latter spitzes the small relative size of the central cavity is noticeable. Fig. 193, Plate XLVII, shows successive transverse sections of a spitz from 3½ mm. to 1¼ mm. diameter; the lower part is obscured by silicification; the upper part shows four rows of outer wall pores to the intersept. Fig. 194 is of a 3¼ mm. spitz coated externally and with endothecal tissue in the central cavity. A spitz of 5 mm. to 3 mm. diameter is shown in Plate XLVII, Fig. 195; this has a slightly fluted outer wall, with two rows of pores to each intersept.

Part of an unusual cluster of Coscinocyathus spitzes, surrounded by exothecal tissue, is shown in Plate XLVII, Fig. 196. We regard the latter as an incrusting or parasitic organism; the state of preservation, however, owing to the presence of much extraneous silicification in the specimen, prevents correlation with Exocyathus or other investing forms.

Genus *Coscinoptycha*, Taylor.

An interesting spitz is figured in Plate XLVII, Fig. 197. It is unusual in having the outer wall pores much larger than the inner, and is of the type described by Taylor as *Coscinoptycha convoluta* and the closely related species with narrower intervallum described by us as *Coscinoptycha unilinearis*. Taylor considered the coarse pored wall as the inner one; he had only expanded fragments from the upper part for study, but our specimens show clearly that the coarse pored wall is the outer one. In view of the unusual shape and details it is desirable to retain Taylor's generic name with this form as genotype. But his *Coscinoptycha bilateralis* is, in details, of the usual *Coscinocyathus* type, allied, as Taylor suggested, to *Coscinocyathus australis*, and should be removed to that genus.

Family *Putapacyathidae*, Bedford.

The genotype *Putapacythus regularis* is described in our third memoir, p. 24. It is a very remarkable and well characterised form, having specialised outer and inner walls and numerous clearly defined tabulae, but with septa entirely wanting. We have now found a spitz which appears to belong to this species. It is shown in Plate XLVIII. Fig. 198. The stone was broken across when found, so that the spitz was in two pieces A and B; we afterwards ground away part of the outer wall of A to expose the inner wall and tabulae, as shown in C. The spitz, which is from 1½ to 1¼ mm. diameter, does not show outer wall pores; probably these are obscured by silicification. The inner wall is vertically ribbed and has a line of pores between each pair of ridges. Tabulae are seen but no septa. The lower part of B is missing to such an extent that only a slip of outer wall remains with the edge of four tabulae; no doubt the inner wall was originally present at this level. It is to be noted that the evidence is insufficient yet to identify this spitz as being completely of "Alphacyathus type." We refer to this point again in connection with the next family.

APPENDIX TO ORDER AJACICYATHINA.

New Family *Sigmocoscinidae*.

Genus *Sigmocoscinus*, Bedford.

The genotype *Sigmocoscinus sigma* was described by us in our third paper, p. 29, Plate XXII, Fig. 93. The genus was defined as cups with regular straight septa. tabulae of the normal *Coscinocyathus* type and continuous anular sigmoid plates inside the inner wall. It may be remarked that, though these plates appear continuous in an inner view of the inner wall surface (Fig. 93E), the ends of the septa project inwards to some extent to join the sigmoid plates, so that in trans-

verse section an appearance may be given like that of the inner wall of *Coscinocyathus papillipora* (Plate III, Fig. 18a) which we now place in the same genus *Sigmocoscinus*. The mode of development of this type of inner wall is shown in the spitz now to be described, which is certainly of this genus and probably of the species *papillipora*.

This spitz, illustrated in Plate XLVIII, Fig. 1997, has some remarkable features. When first exposed the drawing A was made of the surface, and also a transverse section B as seen on the edge of the stone, the total diameter being 3½ mm. at the top of the spitz. Successive longitudinal grindings were then made, and the re-etched surfaces drawn at C, D, E, more in width and more in length towards the spitz being exposed each time. The tangential section, C, through the intervallum of the upper part shows septa and tabulae and the papilliporous outer wall pores. The tangential section, D, grazes the inner wall of the upper part of the spitz. The angle of grinding was then slightly changed in E, showing, at the top of the drawing, a nearly radial longitudinal section of the inner wall about the middle of the spitz, and bringing out the sigmoid inner wall structure; the lower part of the drawing shows a longitudinal section grazing the lower part of the inner wall, this section extending to the hemispherical termination of the spitz, which is here 1¼ mm. diameter; in this section transition is seen from simple normal pores of the inner wall below to sigmoidal pore-plates above. Septa do not appear to extend to the lowest 3 mm. of the spitz, but two transverse structures, which, though apparently without pores in the intervallum, seem to represent tabulae, are present near the tip. Finally the tip of the spitz was ground away transversely to show three successive transverse sections, F, G, H, of the lowest part; F (at level F in E) shows the bottom of the inner wall, seen from below, which is apparently closed, porous and tuberculated; G (at level G in E) shows from below the lowest "tabula," which appears to cross through the central cavity and to be without pores except for three within the central cavity; H (at level H of E) shows the porous inner wall; in none of these three sections have septa yet put in an appearance, and in all of them outer wall pores, if originally present, are obscured by siliceous thickening.

Sigmocoscinus specimens are extremely rare, so that we were fortunate to find a spitz in such good condition, and to be able to make out considerable detail; at the same time, it is realised that, before building too much on the information it gives, comparison with further specimens is much to be desired. Present information indicates, for this genus, a spitz which differs considerably from the Alphacyathus type, whilst differing still more strongly from the *Archaeopharetra* spitz of *Metacyathina*.

Order *METACYATHINA*, Bedford.

This ordinal name was used in our second memoir (1936), but considerable additional information is now available. The spitz of Archaeopharetra type is now found to be the distinctive feature of the order. This spitz commences as a small conical tube with transverse partitions; as the tube enlarges rod-like processes grow from the partitions, and, later, the partitions appear to give rise to "dissepiments" and the rods to trabecular tissue. In some of the most characteristic members of the order, whilst the basal portions have the abovementioned trabecular and dissepimental structure, without inner wall or central cavity, the upper portions develop inner wall and central cavity and the irregular trabecular tissue gives rise to clearly-defined radial septa. It now appears certain that regular septate archaeos arise from spitzes of two distinct types, the Alphacyathus and Archaeopharetra types respectively, and that knowledge of the embryology is essential to a natural classification. The archaeos present some remarkable examples of convergence. A complete system of classification is not yet attainable, but, among forms of which only fragments of the adult form are known so far, it may be said that the following features suggest relationship to Metacyathina, viz.: synapticulae, dissepiments, compound-reticular and irregular walls "wire-netting" and coarse-pored septa; some of these features, however, are absent in upper parts of some species actually traced to Metacyathus-like bases.

Family *Metacyathidae*, Bedford.

Genus *Archaeopharetra*, Bedford.

Some of the specimens described under this head are no doubt spitzes of other genera of Metacyathina, but the following new species *Archaeopharetra vologdini* has been traced from an Archaeopharetra spitz to a quite distinctive upper part.

Archaeopharetra vologdini sp. nov.

A spitz of this species is shown in Plate XLVIII, Fig. 200. At A is exposed the lower part of the spitz in longitudinal section, most being just below the outer wall. This part contains about eight transverse partitions, with a few irregular protuberances and ranges from 2 mm. diameter above to ½ mm. below. Transverse sections of this part at levels B to G are shown in B to G. The spitz was then ground away further in the stone, giving sections I, J, and K. By the time the topmost section was reached, at 3 mm. diameter, a symmetrical structure had developed. The exterior has a fluted surface, resembling (? *Archaeocyathellus*) *floreus*, but the internal structure is far more open than that of *Archaeocyathellus*; the inner wall is a very open structure and inner and outer walls are still connected by widely spaced rods rather than by septa.

These features are also shown in two other specimens, Plate XLIX, Figs. 201, 202.

Other South Australian genera of this family are *Metaldetes* Taylor and *Metacyathus* Bedford; both of these genera have well developed radial septa and inner walls in the upper part, and irregular dissepimental and trabecular tissue without inner wall or central cavity in the lower part, and almost certainly develop from a spitz of Archaeopharetra type. *Paranacyathus* Bedford, containing a considerable variety of species, also appears to belong to this family, and the same may be said of *Ardrossacyathus* Bedford. *Metaldetes* is described by Taylor and the other genera in previous pages of these memoirs.

Another interesting spitz of Archaeopharetra type is shown in Plate XLIX, Fig. 203. The small specimen about 8 mm. long by 4 mm. diameter, shown in three successive longitudinal sections in Fig. 204, is of Archaeopharetra spitz type. It appears to be closed at the upper end except for a tubular orifice, and may illustrate a stage in growth.

The following highly specialised South Australian genera are probably related to this family, though in many cases the development is not sufficiently known, viz.: *Archaeofungia* Taylor and *Metafungia, Sigmofungia, Sigmocyathus* and *Copleicyathus*, Bedford.

Among non-Australian archaeos it is suggested for consideration that the following, when their development is known, may be found to show relationship to the family Metacyathidae.

Archaeocyathus profundus		Billings
(= Cambrocyathus Okulitch)		
do.	atlanticus	do.
do.	septofidis	Vologdin
Anthomorpha		Bornemann
Protopharetra	radiata	do.
Altaicyathus		Vologdin
Claruscyathus		do.
Loculicyathus		do.
Retecyathus		do.
Sibiricyathus		do.

Family *Metacoscinidae*, Bedford, 1936.

The genus *Metacoscinus* Bedford 1934 has "wire netting-like" septa, and sporadic "tabulae" of peculiar type; it grows from an irregular base without central cavity and from a spitz of Archaeopharetra type similar to that figured in Plate XXX, Fig. 123. Two very similar species occur at the Ajax Mine, one, a fine meshed species with 2 mm. intervallum, is (Archaeocyathus) retesepta Taylor, the other, with coarse mesh and 5 mm. intervallum is *Metacoscinus reteseptatum* Bedford. Another species with very dense outer wall, thrown into irregular bulges, is *Metacoscinus insigne* Bedford.

Besides this genus we have found at the Ajax Mine a few scarce and rather puzzling specimens of which the tabulae are strongly arched, but otherwise resemble those of *Coscinocyathus*, whilst the base is of irregular structure and there are other anomalous features not usually met with in *Coscinocyathus*. These fragments were described in our second paper, p. 18, as *Paracoscinus mirabile* and are placed provisionally in the family Metacoscinidae.

Fragments of another very remarkable type *Pycnoidocoscinus pycnoideum* Bedford have strongly arched tabulae, and the outer wall is thrown into flanges, resembling those of Pycnoidocyathus. Details, alike of both walls and tabulae, differ widely from those of *Coscinocyathus*. The base and spitz of this striking but very rare species have not yet been found. It is placed provisionally in the family Metacoscinidae.

New Family *Flindersicyathidae*.

Members of the family appear to grow from an irregular base or spitz of Archaeopharetra type. The most characteristic feature of the upper part is the inner wall, consisting of large canals directed inwards and upwards, into the central cavity. The septal structures present a remarkable evolutionary series passing from species with an unusually oriented trabecular mesh through those with more or less waved septa to others with straight well defined septa. Details of many species are given in our former papers and in Taylor's monograph. All the species are relatively scarce and specimens are usually much obscured by secondary silicification; it is exceptionally difficult to find a clear and well defined spitz. The small spitz shown in Plate XXIX, Fig. 120A, is almost certainly one belonging to this family, and the larger spitz of a coarse-structured species shown in Plate L, Fig. 205, shows transition from the Archaeopharetra-type base to the inwardly directed inner-wall-canals and trabecular septal mesh in the upper part. (Compare *Flindersicyathus rete*).

Genus *Flindersicyathus*, Bedford.

The genus was proposed on p. 28 of our fourth memoir and details given there and in previous pages. It is characterised by an intervallar tissue of curved lattices and an inner wall with large canals leading upwards and inwards into the central cavity.

Flindersicyathus decipiens, Bedford, may be taken as genotype. Other South Australian species are (*Spirocyathus*) *irregularis* and *radiatus* and (*Pycnoidocyathus*) *ptychophragma* and (*Protopharetra*) *rete* Taylor and *Flindersicyathus circliporus, tabulatus* and *macdonnelli* and (*Spirocyathus*) *multifidus, major* and *speciosus* Bedford.

Genus *Pycnoidocyathus*, Taylor.

Taylor's definition of the genus is "cups in which the outer wall is thrown into deep horizontal bulges. Usually synapticulate. Septa within the peripheral bulges highly irregular." The first species he describes, which may be taken as the genotype, is *Pycnoidocyathus synapticulosus*. We wish to redefine the genus as "cups

in which the outer wall is thrown into deep horizontal bulges. Often synapticulate. Septa in part defined and radial, in part wavy, and sometimes giving place to irregular trabecular tissue within the bulges. Inner wall has large channels leading upwards and inwards into the central cavity." Our classification differs considerably from Taylor's. He separated these forms, as members of the family "Archaeocyathidae," from such species as *Flindersicyathus irregularis*, which he placed among the "*Spirocyathidae*," whereas we regard *Pycnoidocyathus* as evolved from a form like *Flindersicyathus* (see our second memoir, pp. 14, 15).

South Australian species are *Pycnoidocyathus synapticulosus* and *simplex* Taylor, and *maximipora*, *vicinisepta* and *parvulus* Bedford.

Genus *Beltanacyathus* Bedford.

The genus is described in our third memoir, pp. 23, 24. The genotype is *Beltanacyathus ionicus*. We place it in this family chiefly on account of the very characteristic inner wall. The spongy outer wall is of a nature often met with in Metacyathina, but not in Ajacicyathina. The spitz has so far only shown Metacyathine affinity by the presence of dissepiments, but more material is desirable. In placing this striking form in the present family we suggest that the straight septa have evolved on the same lines as the similar septa of *Pycnoidocyathus maximipora*. Taylor's *Archaeocyathus wirrialpensis* appears to belong to this genus.

Ethmophyllum whitneyi Meeck, and *marianum* Romer have features of resemblance to *Beltanacyathus*.

Family *Syringocnemidae* Taylor.

Genus *Syringocnema* Taylor.

The well-known and clearly defined genotype *Syringocnema favus* was described by Taylor in 1910 and details as to the nature of its remarkable structure were added in our second memoir, p. 16, Fig. 74. We regard this structure as having been evolved from a type comparable to *Flindersicyathus ptychophragma*.

A spitz of *Syringocnema* is drawn in Plate L, Fig. 206 and shows an irregular structure near the tip, with trabeculae and dissepiments, which has considerable resemblance to the Archaeopharetra type; from this point it develops rapidly to the characteristic *Syringocnema* structure above. It is highly probable that the little spitz drawn in Plate XXX, Fig. 122, is of *Syringocnema;* the relationship of transverse partitions to the developing tubular elements is clearer in this specimen and so is its resemblance to the Archaeopharetra type of spitz; unfortunaetly this spitz does not go far enough upwards to make its identity with *Syringocnema* certain.

New Order *CROMMYOCYATHINA*.

There is a number of problematic forms whose relation to one another and to the better known orders of Archaeos remains doubtful. Among them growth in irregular concentric rings is frequent, and the above name is suggested from the resemblance to the successive coats of an onion (Greek—Krommuos). Another frequent character is that of forming an incrusting or parasitic investment to various species of Archaeos.

Labyrinthomorpha.

Vologdin in 1926/1931 figured one of these incrusting organisms under the name of *Labyrinthomorpha tolli*. A rough sketch after Vologdin's figures is shown in Plate LI, Fig. 207, A being the complete organism, here investing two specimens of *Coscinocyathus* and a *Protopharetra*, and B being a sectional view of the structure. He described this in 1937 briefly as follows: "The forms essentially consist of an irregular network of vesicles, sometimes porous"; we have not been able to refer to his 1926 description. He made a family *Vesiculoidae* for this genus.

Ajacia.

In our second memoir, pp. 9, 10, fig. 37, we described a remarkable specimen of an incrustation surrounding several different Archaeo spitzes under the name *Ajacia ajax;* at first we thought it might be an Alga, but now consider that it is in all probability an incrusting Archaeo. Unfortunately fine detail is obscured in this specimen, but it is seen to be laminated, the laminae following the external mamillated contour.

Exocyathus.

The structure of the genotype, *Exocyathus australis*, is described at length in our fourth memoir, pp. 32-34, Figs. 132-136. This was considered by Taylor as roots or "exotheca," but we think that the balance of evidence definitely favors its being of a parasitic or incrusting nature. The fine structure of *Exocyathus*, which is well brought out by etching the silicified specimens of the Ajax Mine, seems very different from that of any other Archaeo. It consists of narrow radial plates, greatly elongated lengthways; in transverse section these, in parts of the organism which are arranged in broad concentric lamellae, stretch across the thickness of each lamella, as in Fig. 133A; but they also tend, in parts of the organism, to bud out from the surface of the lamella as cylindrical columns, as in Fig. 135 A and B, and these cylinders may become independent distally as in Fig. 146A. The cylindrical processes are shown in Fig. 132, A, B, C; in the central parts the constituent plates become crumpled and anastomosing, and the structure has something like that of sticks of the sweetmeat called "Edinburgh Rock." There is no separate outer wall to these cylinders, the surface being formed simply by the regularly disposed outer edges of the longitudinal plates, which are here united by minute connecting bars.

In our former description we were doubtful whether

to consider these cylinders as proximal or distal, but it seems that the latter is the more likely explanation, and that none of them can be regarded as spitzes. Indications of the mode of origin of *Exocyathus* may perhaps be gathered from specimens figured in 133 B and 134 A, B. In Plate LII, Fig. 209, is shown a thin, scaly, more or less circular patch of what appears definitely to be a parasitic growth on the inner wall of an expanded fragment of *Paranacyathus margarita*. The surface of this is concentrically smeared and round the edge is seen a ring of small plates regularly and radially arranged. This cannot be actually identified as an early stage of *Exocyathus*, but it is suggestive of that genus, and it may indicate the mode of origin of other forms such as *Labyrinthomorpha* and *Ajacia*. The smeared pellis of this specimen resembles the coating often met with on the lower parts of various Archaeos, particularly Metacyathina. This specimen is the nearest approach we have seen in this group to anything which might be taken to correspond with the spitz of normal Archaeos, in the sense that it shows growth from a central point; but here the growth is discoidal instead of conical. On grinding through the pellis (Fig. 205 B) structural elements could not be traced to the centre, and pores of the *Paranacyathus* wall were exposed.

In Plate LI, Fig. 208, are given four successive sections of an irregular outgrowth from the outer wall near the base of a *Metacoscinus*. In the first section A the striated pellis of the outgrowth is seen at the right, and internally is seen a series of partly regular oriented plates and partly irregular tissue, having no resemblance to the "wire-netting" septa of *Metacoscinus*. In the fourth section D the peculiar tissue of the outgrowth has given place to the normal basal structure of *Metacoscinus*. This specimen seems to be best interpreted as a parasitic growth allied to the group under discussion, growing on *Metacoscinus*.

Metaldetimorpha.

A description and several figures of this genus are given in our fourth memoir. Some of the specimens show three or more concentric zones of growth, see Fig. 130 A and C. The greater part of the tissue in these zones is of a vesicular character, with several rows of vesicles to the zone, and without marked elongation of the vesicles lengthways; in this respect the structure differs considerably from that of the concentric zones of *Exocyathus*. In some of the specimens the successive zones are separated from one another by a remarkable type of wall, which thus has vesicular tissue on each side of it. It is especially to be noted that these walls are tangential in their orientation, parallel to the outer surface, in contrast with the transverse tabulae and radial septa found in other Archaeos; apart from the outer and inner walls of other Archaeos this appears to be the only instance of such tangential structures within the intervallum. Such a tangential wall is seen in Fig. 127 bb, and 127 C bb in transverse section; a surface, i.e., tangential, view of a similar wall is shown in Plate XLI, Fig. 159 B. The tissue near the wall has, in longitudinal section, a regular honeycomb structure and the wall itself is formed by an oriented thickening of all the radial walls of the honeycomb, thus encroaching on the lumina and forming a porous sheet, the pores of which become progressively smaller towards the centre of the sheet; each pore would thus have an hour-glass shape when seen in a transverse section of the organism.

Some *Metaldetimorpha* specimens show remarkable patches of coarse septa-like structure lying with various orientations among the vesicular tissues; see Plate XXXII, Figs. 128, 130 A, 130 B, and Plate XXXIII, Fig. 130 F, G.

"Archaeocyathus profundus."

Billings' original description and figures published in 1865 refer to a large Archaeo species which attained a length of more than a foot with a diameter of from two to four inches. The outer surface was thrown into anulations like those of *Pycnoidocyathus*; it had clearly defined radial septa, thin and closely crowded together, and the figures show a few synapticulae. The outer wall and the thin inner wall were mentioned, but evidently the preservation was not sufficiently good for detailed description.

In 1886 appeared two descriptions and sets of plates by Walcott and Bornemann respectively which introduced complications. Walcott figured in his Plate I, Figs. 1a and 1 an outline and enlargement "of a portion of a transverse section of a specimen in which the growth appears to have been in layers. Collection U.S. National Museum." Walcott appears to have confused one or two other species with that of Billings. A similar confusion is evident in the beautiful photograph published by Bornemann as of *Archaeocyathus profundus* in his Plate 32. We give in Plate LII, Fig. 210, a crude sketch of this photograph. Bornemann's specimen was from Billings' type locality, Anse au Loup, Canada; he says, "The whole arrangement shows a concentric structure like the annual rings of plants." It is not easy to reconcile even the central part of this specimen with Billings' description. As regards the more or less concentric layers which surround the central Archaeo, they have decided resemblance to some of our specimens of *Metaldetimorpha*; on the other hand, it may be said that they have little resemblance to *Exocyathus*, except for the concentric arrangement.

Calathium.

Billings, in his 1865 memoir, describes, p. 337, fig. 325, a fossil from Pistolet Bay, Newfoundland, under the name *Calathium anstedi* or *crassum*. We give a rough sketch of his figure in Plate LII, Fig. 208. He says, "the whole fossil appears to be composed of a number of concentric laminae." His *generic* description of *Calathium* does not appear to contemplate a con-

centric structure of this kind; his genotype *Calathium formosum* is a simple conical cup with very large outer pores (over 1 mm.), regularly arranged in a diamond pattern. The specimen here illustrated is evidently related to our *Metaldetimorpha* and not to the genotype of *Calathium*.

Protopharetra polymorpha.

In Bornemann's 1886 monograph a description and photographs are given of his genotype *Protopharetra polymorpha*; one of these photograhs is sketched roughly in our Plate LII, Fig. 211. Bornemann makes the following remarks: "Often there appear within the fibre tissue zones of densely packed fibres which then in cross section appear as a concentric closed ring, but in longitudinal section and oblique section give a very irregular picture of the structure, because one part shows cross sections of distant fibres, another part the fibres united to a porous wall, in which only small round lumina remain open." This description has some resemblance to ours of *Metaldetimorpha yorkei*, (see our Plate XXXI, Fig. 127 and Plate XLI, Fig. 159). Bornemann also says, "On the outer wall one observes sometimes tubular root fibres, consisting of a simple wall which in cross section appear as rings or ellipses." But Bornemann also says that his specimens have mostly a central tubular cavity, which is separated from the surrounding tissue by a delicate sieve-like porous wall formed by union of the fibres. It is possible that more than one species is included in Bornemann's material, one a *Protopharetra* with inner wall, the other an irregular or parasitic growth allied to *Metaldetimorpha*.

Some of these apparently parasitic forms of the order Grommyocyathina may be placed in a new family *Exocyathidae*, with *Exocyathus* as the typical genus. *Labyrinthomorpha* was placed by Vologdin in a family Vesiculoidae.

CLASSIFIED LIST OF GENERA.

The following list of genera of the Pleospongia is classified provisionally on the foregoing lines:

Class PLEOSPONGIA, Okulitch.

Order MONOCYATHINA, Okulitch.
Family Monocyathidae, Bedford.
Monocyathus, Bedford.
? *Tunkia*, Bedford.
Family Rhabdocyathidae, Vologdin.
Rhabdocnema, Okulitch.
Rhabdocyathella, Vologdin.
Yakovlevia, Vologdin.
Family Archaeophyllidae, Vologdin.
Archaeophyllum, Vologdin.
Butovia, Vologdin.
Family Rhizacyathidae, Bedford.
Rhizacyathus, Bedford.

Order ACANTHINOCYATHINA, Okulitch.
Family Acanthinocyathidae, Bedford.
Acanthinocyathus, Bedford.
Pinacocyathus, Bedford.

Order AJACICYATHINA, Bedford.
Family Alphacyathidae, Bedford.
Alphacyathus, Bedford.
Coelocyathus, Vologdin.
Dictyocyathus, Bornemann.
Dokidocyathus, Taylor.
Spirillicyathus, Bedford.
Family Ajacicyathidae, Bedford.
Ajacicyathus, Bedford.
Archaeocyathellus, Ford.
Cadniacyathus, Bedford.
Densocyathus, Vologdin.
Formosocyathus, Vologdin.
Leptocyathus, Vologdin.
Orbicyathus, Vologdin.
Protocyathus, Ford.
Polycyathus, Vologdin.
Sajanocyathus, Vologdin.
Septocyathus, Vologdin.
Somphocyathus, Taylor.
Tumulocyathus, Vologdin.
Ventriculocyathus, Vologdin.
Zonacyathus, Bedford.
Family Bronchocyathidae, Bedford.
Bronchocyathus, Bedford.
Clathrocyathus, Vologdin.
Cyclocyathus, Vologdin.
Ethmocyathus, Bedford.
Tercyathus, Vologdin.
Family Coscinocyathidae, Taylor.
Coscinocyathus, Bornemann.
Coscinocyathellus, Vologdin.
Coscinoptycha, Taylor.
Polycoscinus, Bedford.
Tuvacyathus, Vologdin.
Family Sigmocoscinidae, Bedford.
Sigmocoscinus, Bedford.
Carinocyathus, Vologdin.
Family Putapacyathidae, Bedford.
Putapacyathus, Bedford.
The following genus is of doubtful affinity.
Calathium, Billings.

Order METACYATHINA, Bedford.
Family Metacyathidae, Bedford.
Altaicyathus, Vologdin.

Anthomorpha, Bornemann.
Anulocyathus, Vologdin.
Araneocyathus, Vologdin.
Archaeocythus, Billings.
Archaeopharetra, Bedford .
Ardrossacyathus, Bedford.
Archaeoscyphia, Hinde.
Bicyathus, Vologdin.
Cambrocyathus, Okulitch.
Claruscyathus, Vologdin.
Copleicyathus, Bedford.
Loculicyathus, Vologdin.
Metacyathus, Bedford.
Metafungia, Bedford.
Metaldetes, Taylor.
Paranacyathus, Bedford.
Protopharetra, Bornemann.
Retecyathus, Vologdin.
Sibiricyathus, Vologdin.
Sigmocyathus, Bedford.
Sigmofungia, Bedford.
Tubocyathus, Vologdin.

Family Metacoscinidae, Bedford.
Archaeosycon, Taylor.
Aptocyathus, Vologdin.
Eucyathus, Vologdin.
Metacoscinus, Bedford.
Paracoscinus, Bedford.
Pycnoidocoscinus, Bedford.
Tabulocyathus, Vologdin.

Family Flindersicyathidae, Bedford.
Beltanacyathus, Bedford.
Ethmophyllum, Meek.
Flindersicyathus, Bedford.
Orbicyathus, Vologdin.
Pycnoidocyathus, Taylor.

Family Syringocnemidae, Taylor.
Syringocnema, Taylor.
Syringocyathus, Vologdin.

Order CROMMYOCYATHINA, Bedford.

Family Exocyathidae, Bedford.
Ajacia, Bedford.
Exocyathus, Bedford.
Metaldetimorpha, Bedford.

The following genus is of doubtful affinity.
Nipterella, Hinde.

Family Vesiculoidae, Vologdin.
Labyrinthomorpha, Vologdin.

The development of the following order and its relationship to other orders of Pleospongia is not yet known.

Order HETAIRACYATHINA, Okulitch.
Family Hetairacyathidae, Bedford.
Hetairacyathus, Bedford.

Members of the following order are sponges of hollow spherical, oval, or gastrula-like forms; development not yet known.

Order URANOSPHAERINA, Bedford
Family Uranosphaeridae, Bedford.
Uranosphaera, Bedford.

The following genus is of doubtful affinity:
Haguia, Walcott.

Fig. 160

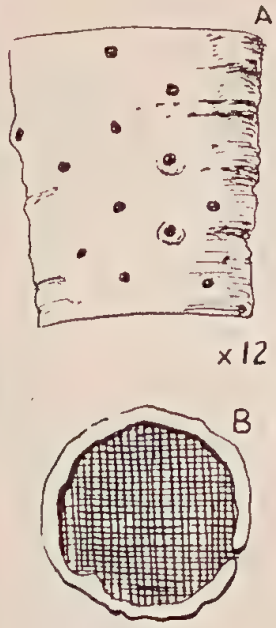
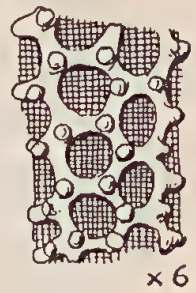


Fig. 161

Fig. 162



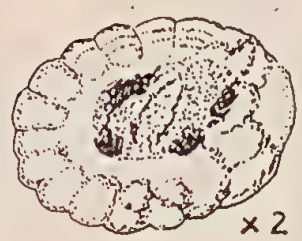


Fig. 163

Fig. 164

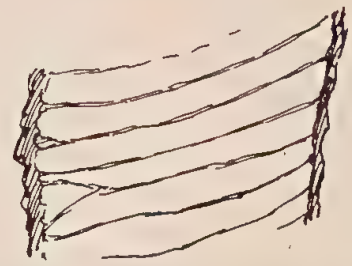
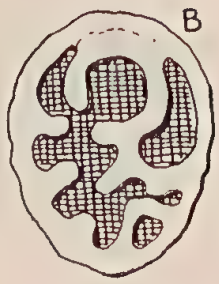


Fig. 165



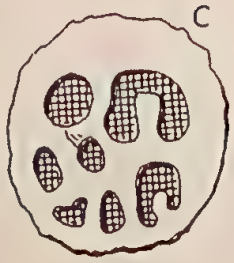


Fig. 166

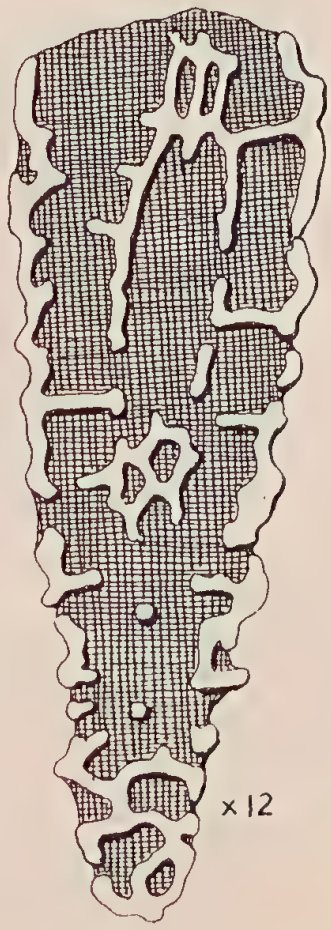
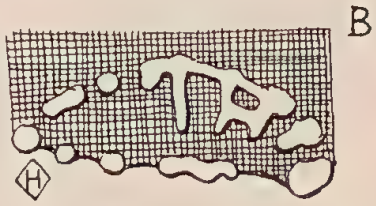
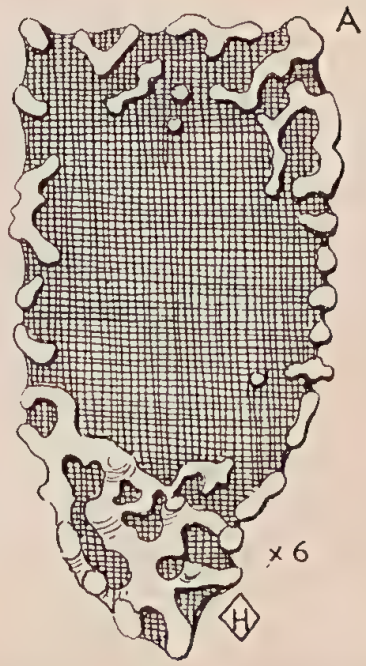


Fig. 167





160. *Monocyathus irregularis spitz.*
161. *Monocyathus porosus spitz.*
162. *Monocyathus spinosus.*
163. *Yakovlevia (after Vologdin)*
164. *Archaeophyllum (after Vologdin).*
165. *Rhizacyathus spitz.*
166. *Acanthinocyathus spitz.*
167. *Acanthinocyathus transiens.*

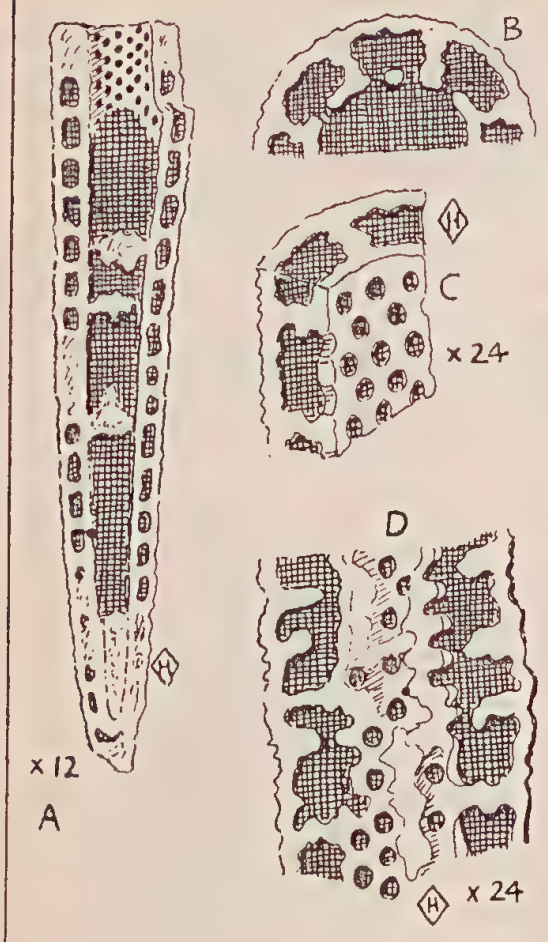


Fig. 168

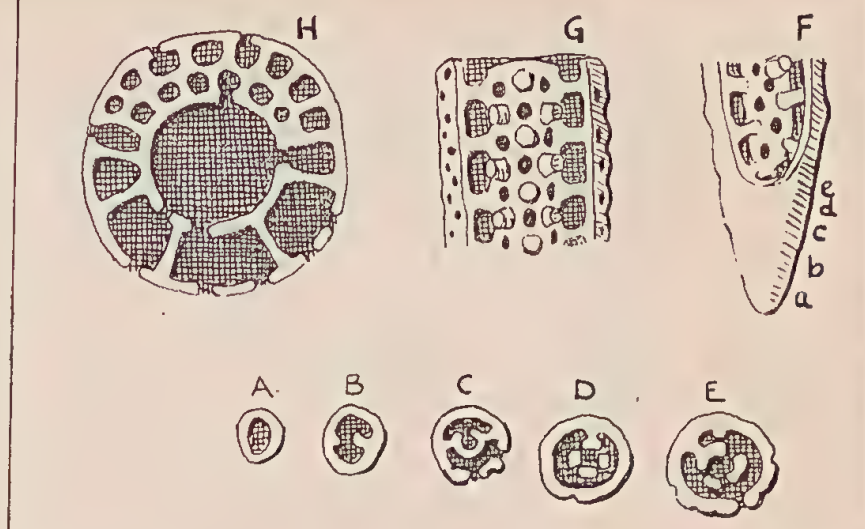


Fig. 169 x 12

Fig. 170

Fig. 172

Fig. 171 x12

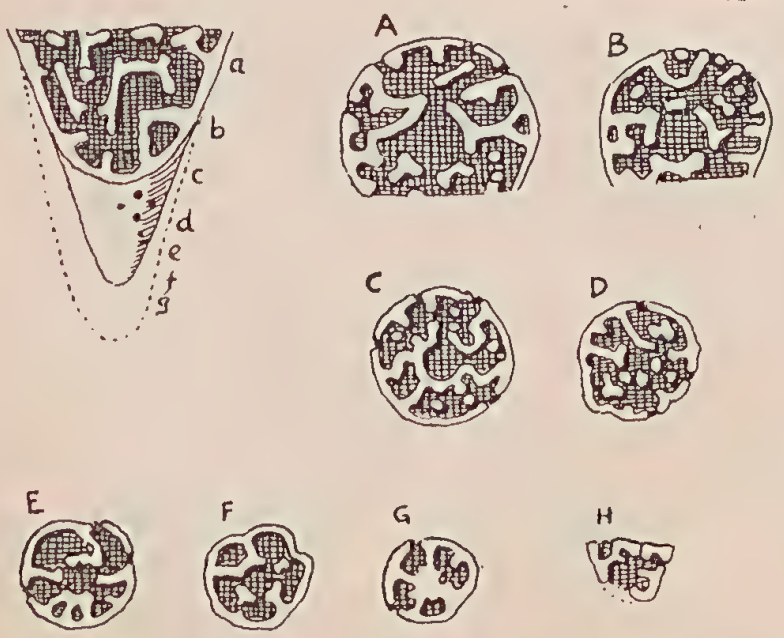
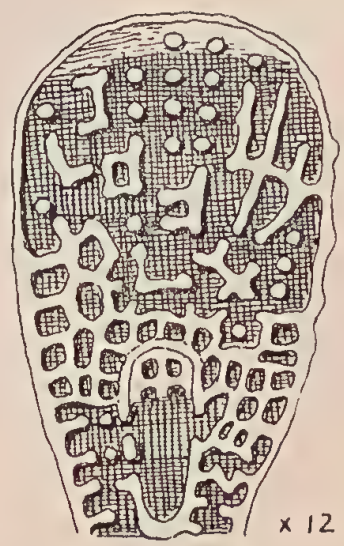


Fig. 173

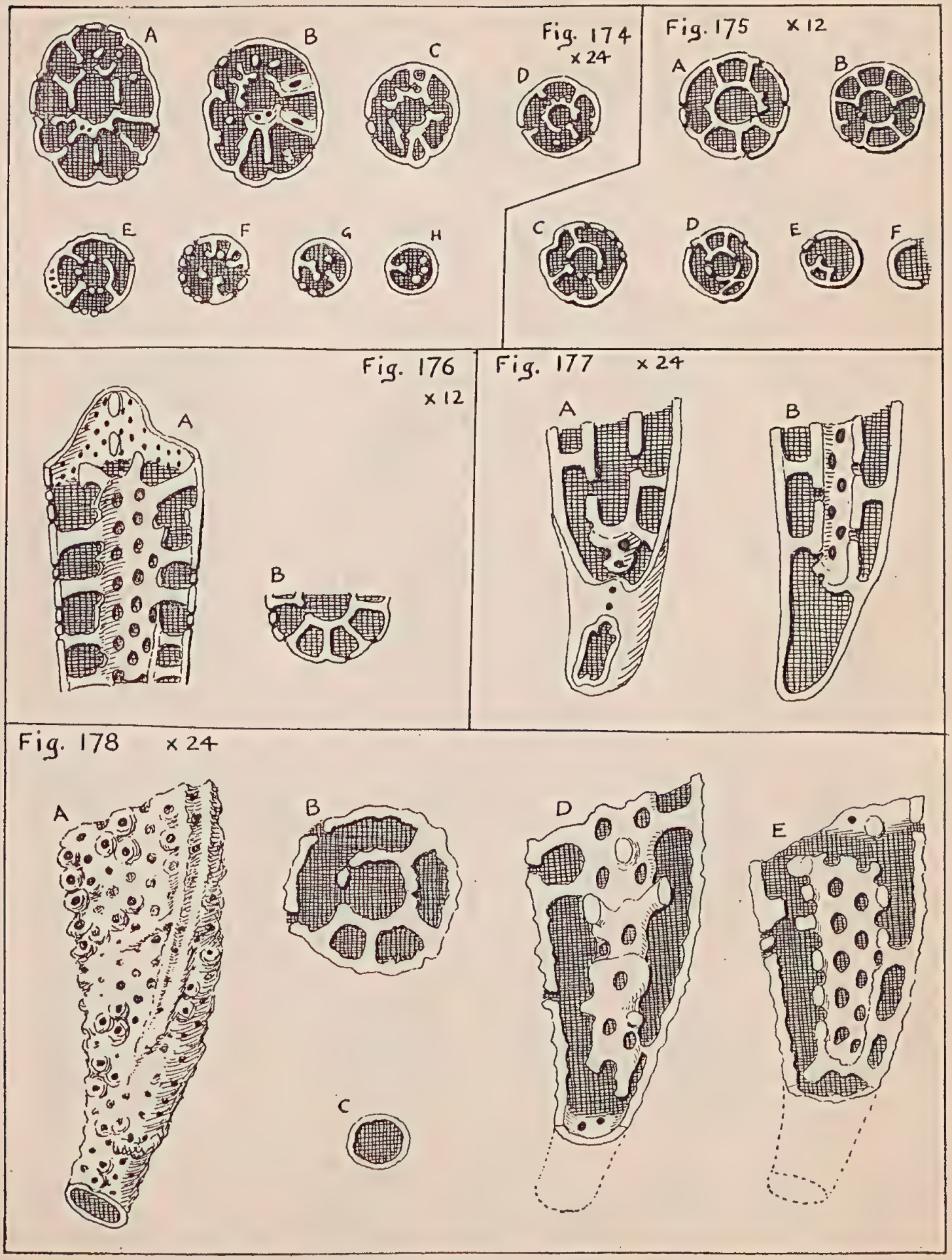


168. *Alphacyathus zero.*

169. *Alphacyathus anularis spitz.*

170. *Dictyocyathus (after Bornemann).*

171, 172, 173. *Dictyocyathus graphicus spitzes.*



174. Spirillicyathus spitz.

175, 176, 177. Dokidocyathus spitzes.

178. Ajacicyathus ajax spitz.

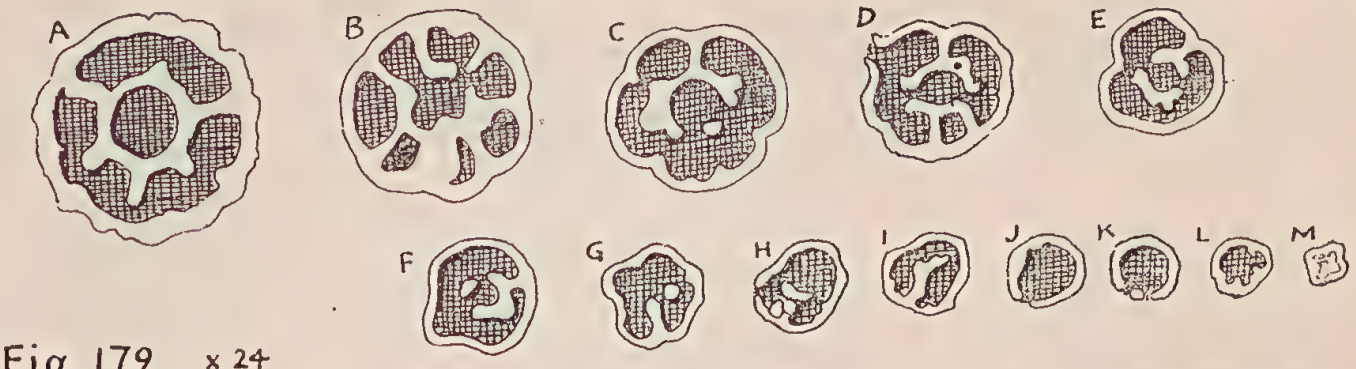


Fig. 179 x 24

Fig. 180
x 24

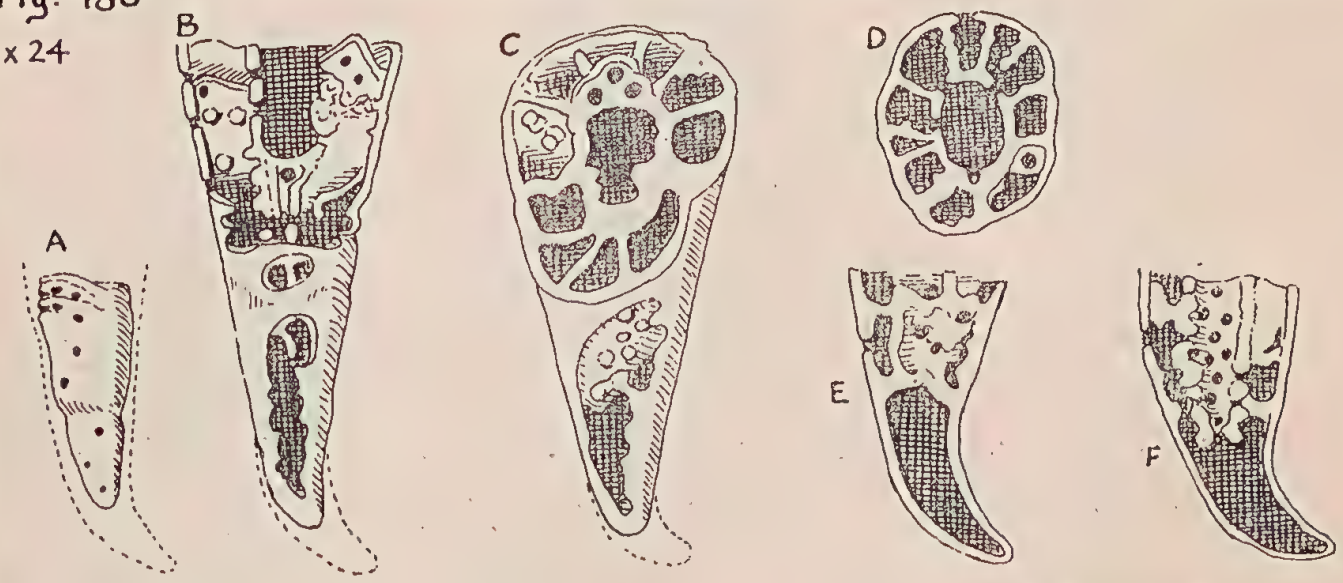


Fig. 181 x 24

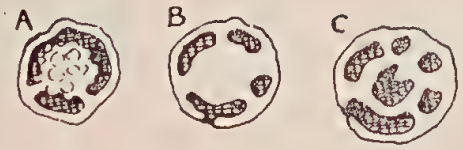


Fig. 183 x 12

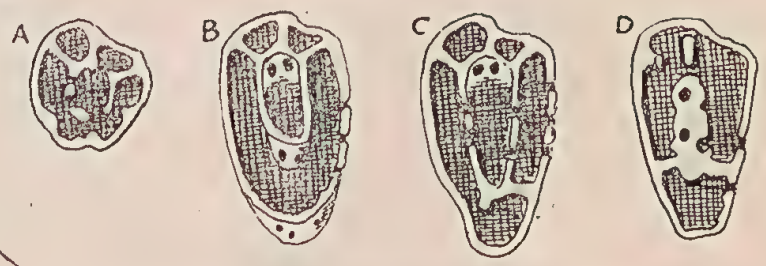
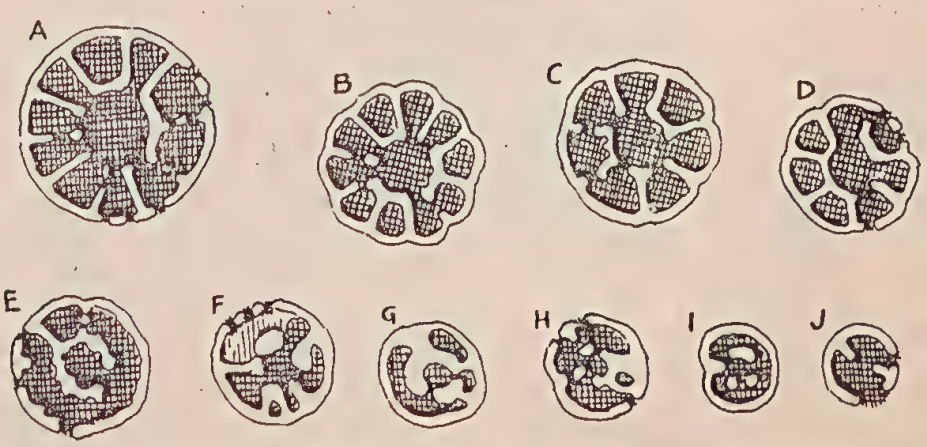


Fig. 182 x 12

Fig. 184
x 24



179, 180, 181, 182, 183, 184. Ajacicyathus spitzes.

Fig. 185

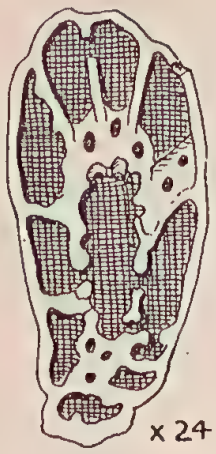


Fig. 186

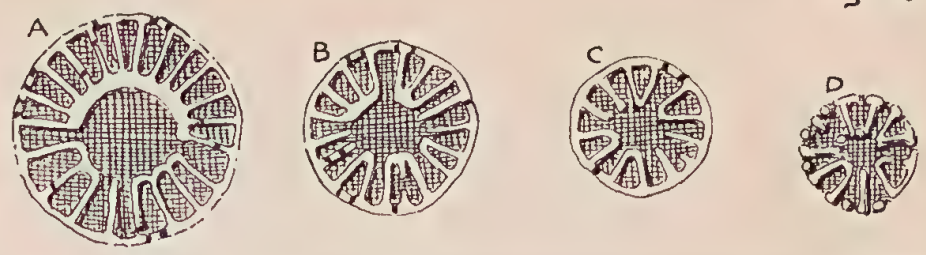


Fig. 187

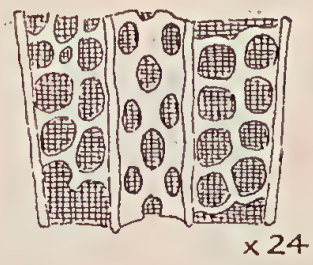


Fig. 188

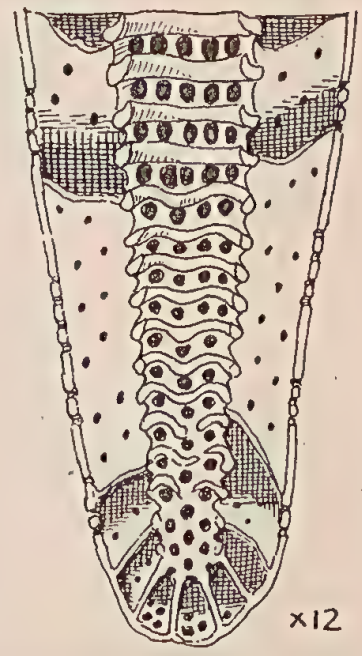


Fig. 190 x24

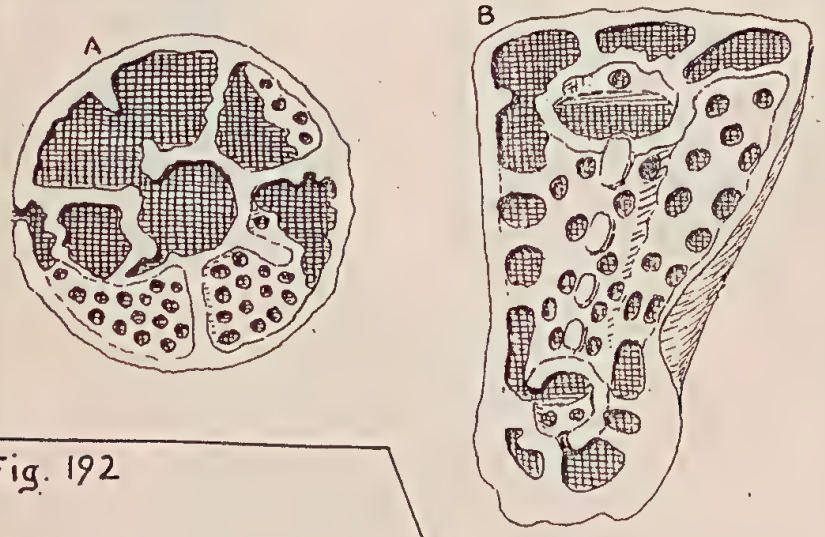


Fig. 189

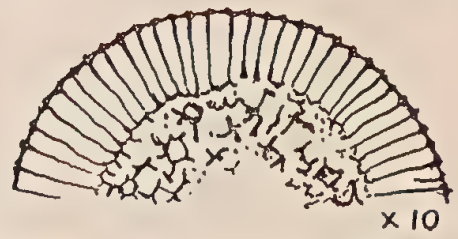


Fig. 192

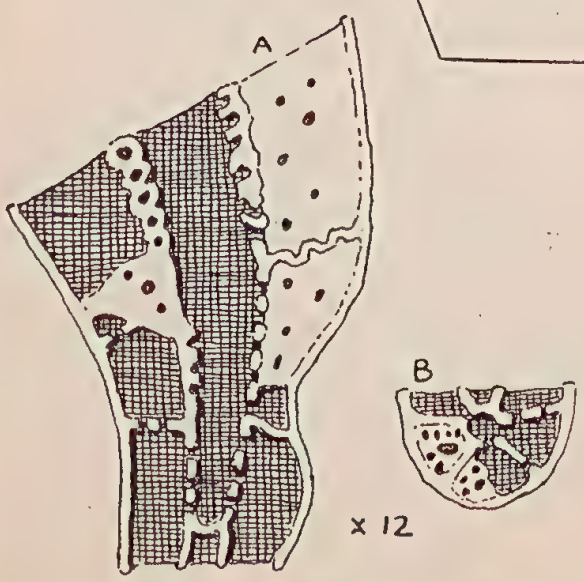
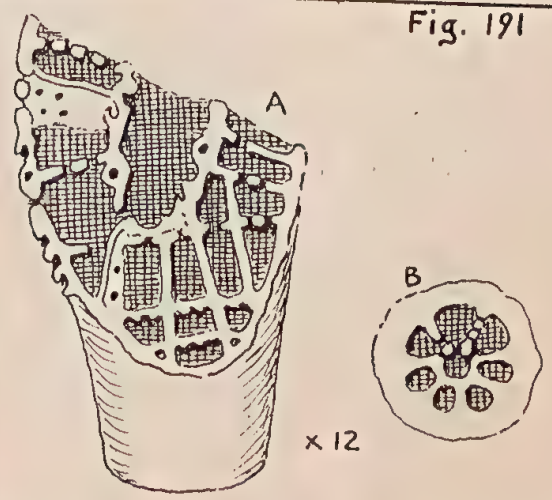
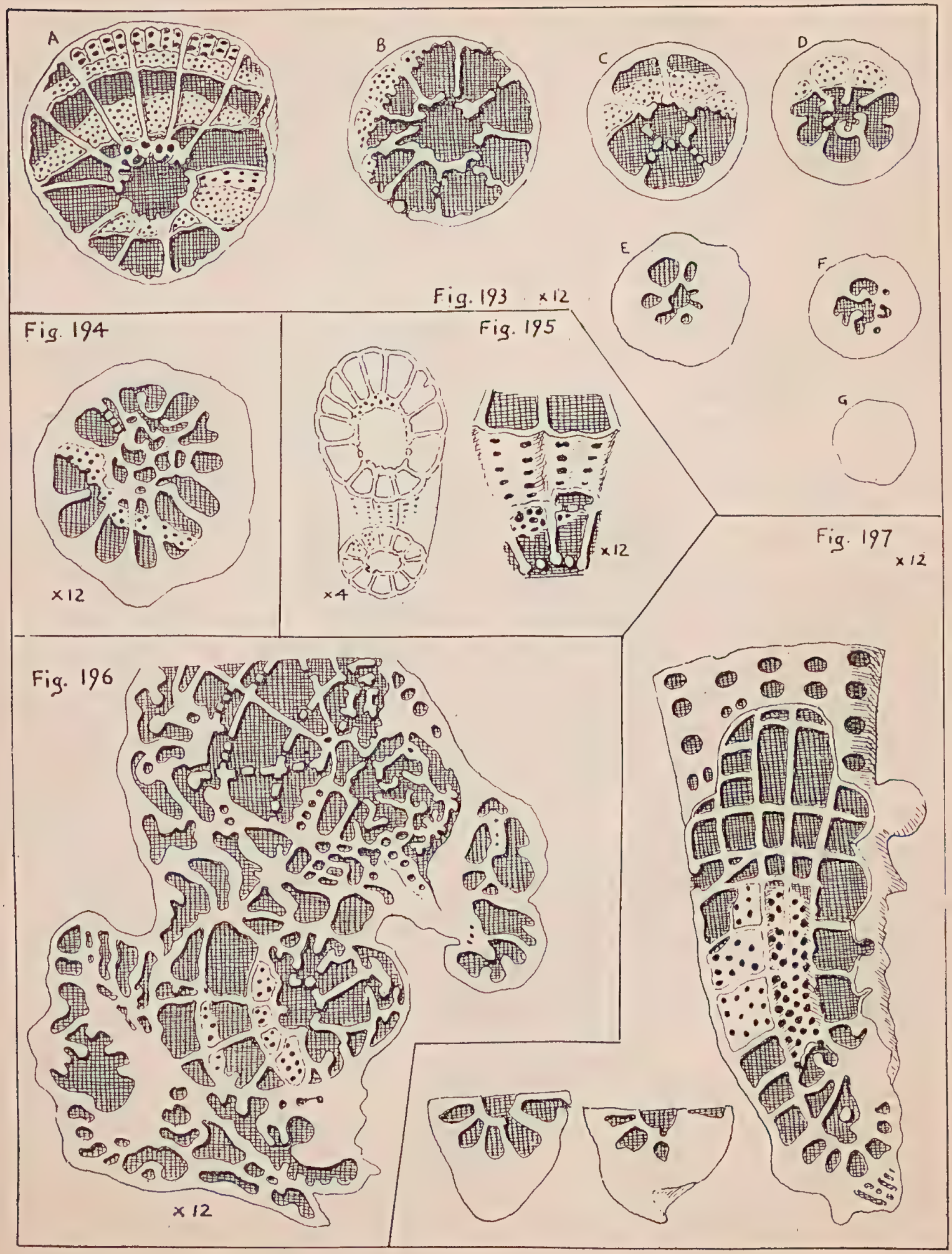


Fig. 191

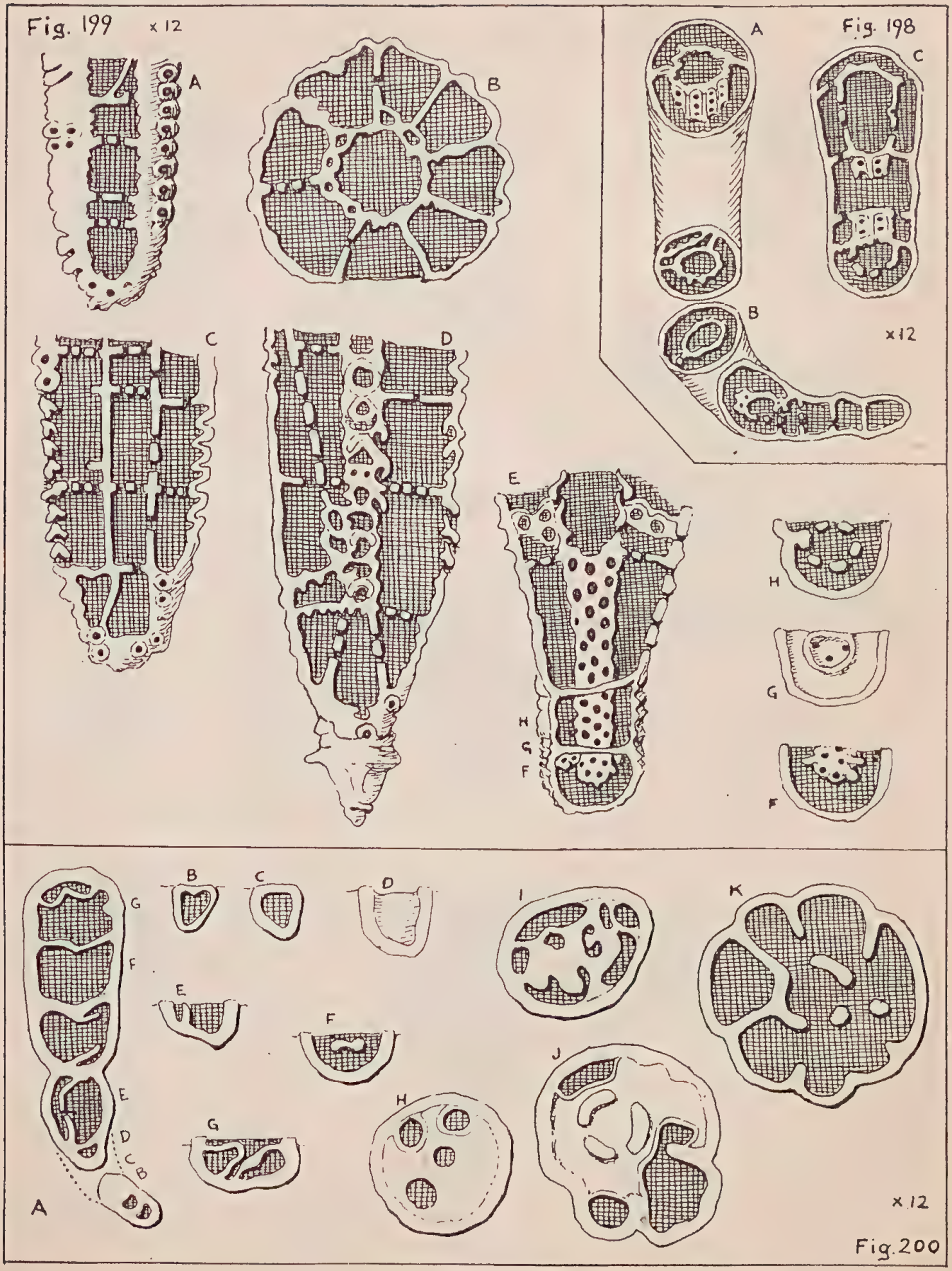


185, 186, 187, 188. Cyclocyathus trachealis spitzes. *190, 191, 192. Coscinocyathus spitzes.*

189. Tercyathus (after Vologdin).



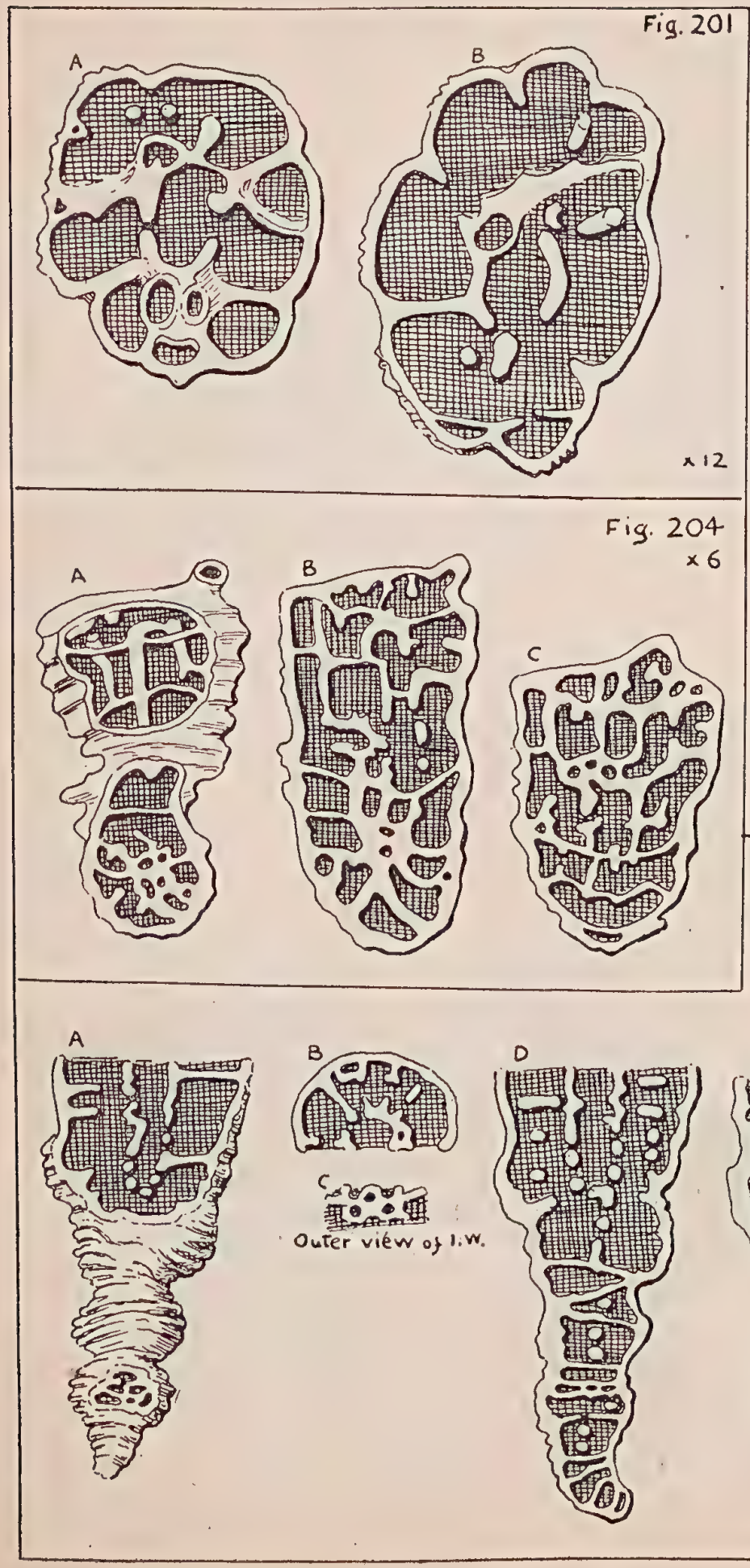
193, 194, 195, 196. Coscinocyathus spitzes. *197. Coscinoptycha spitz.*



198. *Putapacyathus spitz.*

199. *Sigmocoscinus spitz.*

200. *Archaeopharetra vologdini.*



201, 202. Archaeopharetra vologdini. *203, 204. "Archaeopharetra" spitzes.*

Fig. 205
x 5

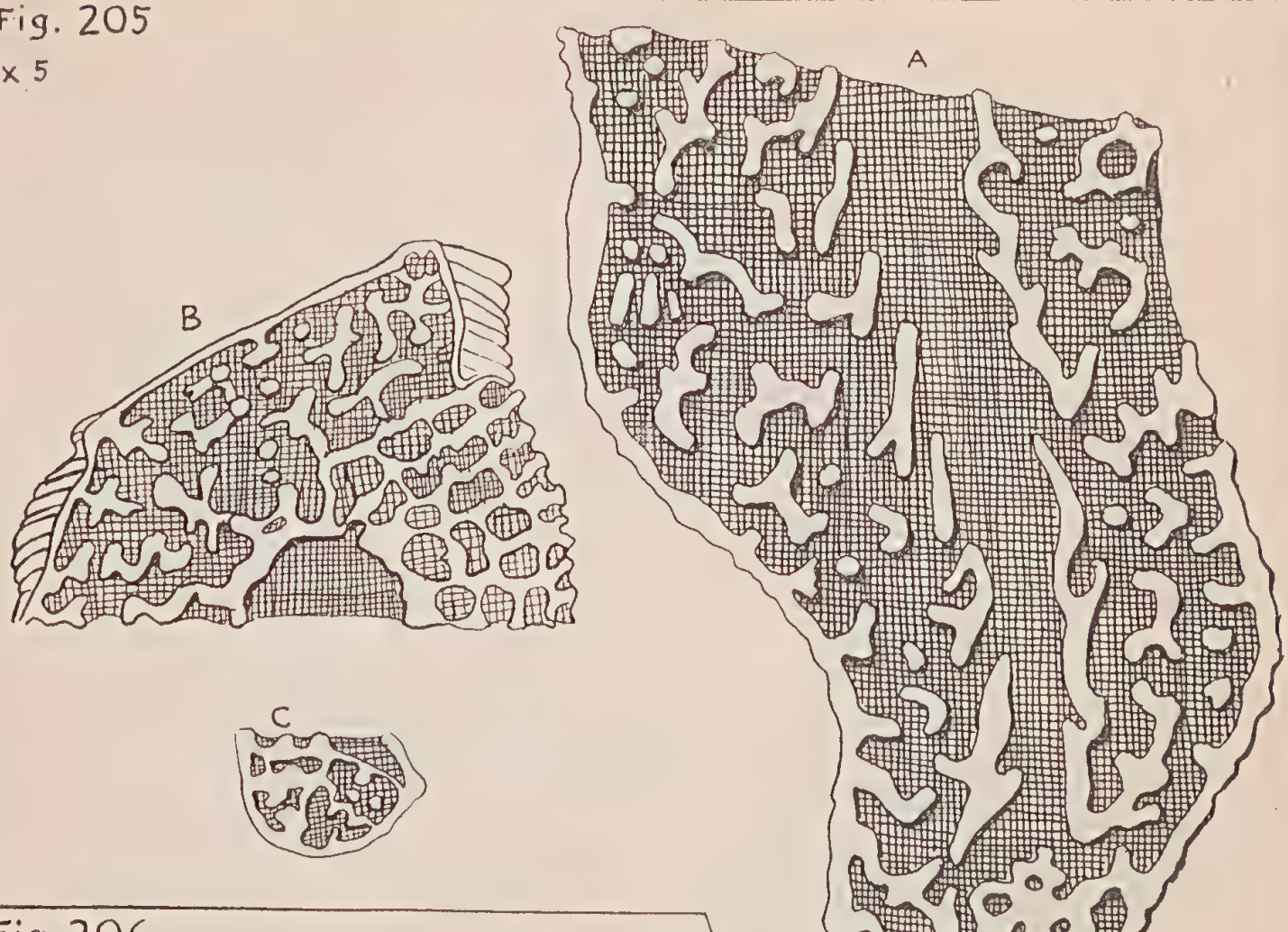
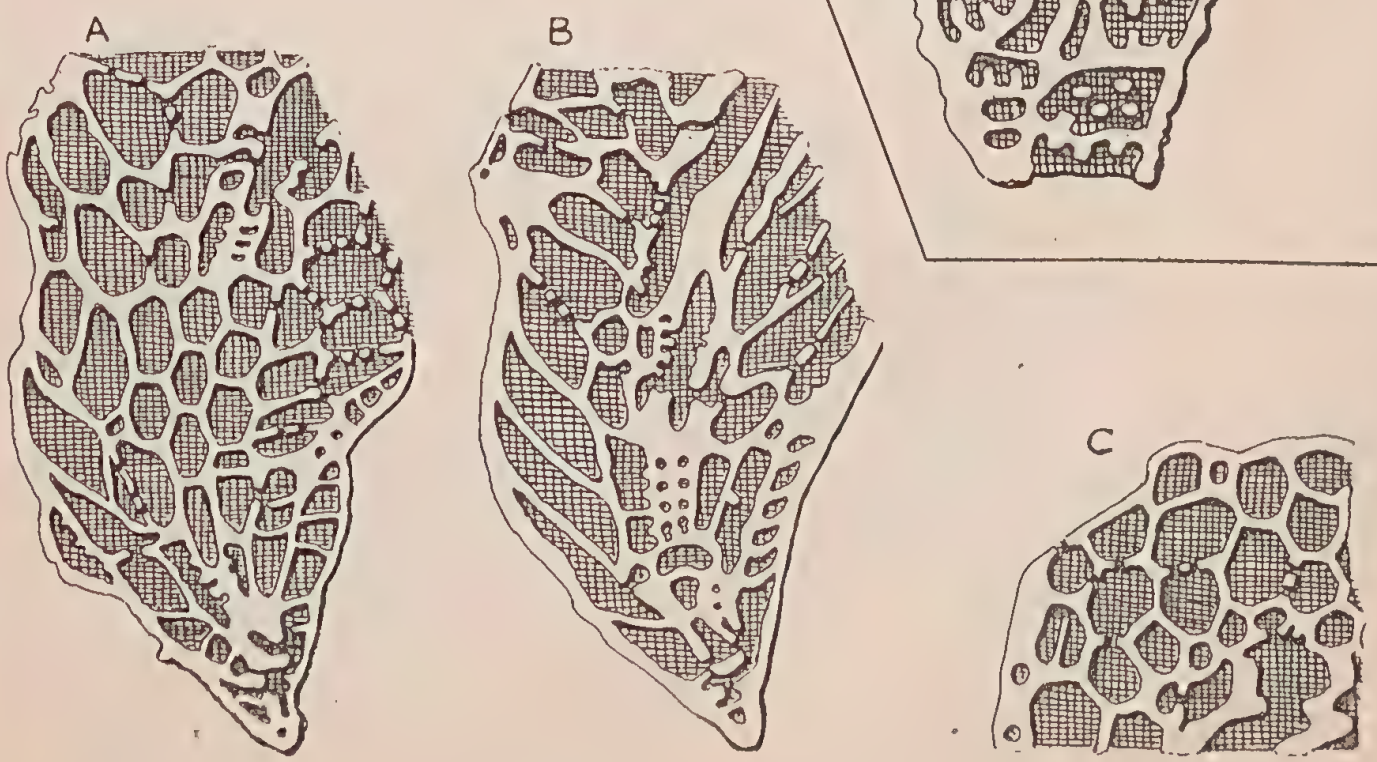


Fig. 206
x 11



205. *Flindersicyathus spitz.*

206. *Syringocnema spitz.*

Fig. 207

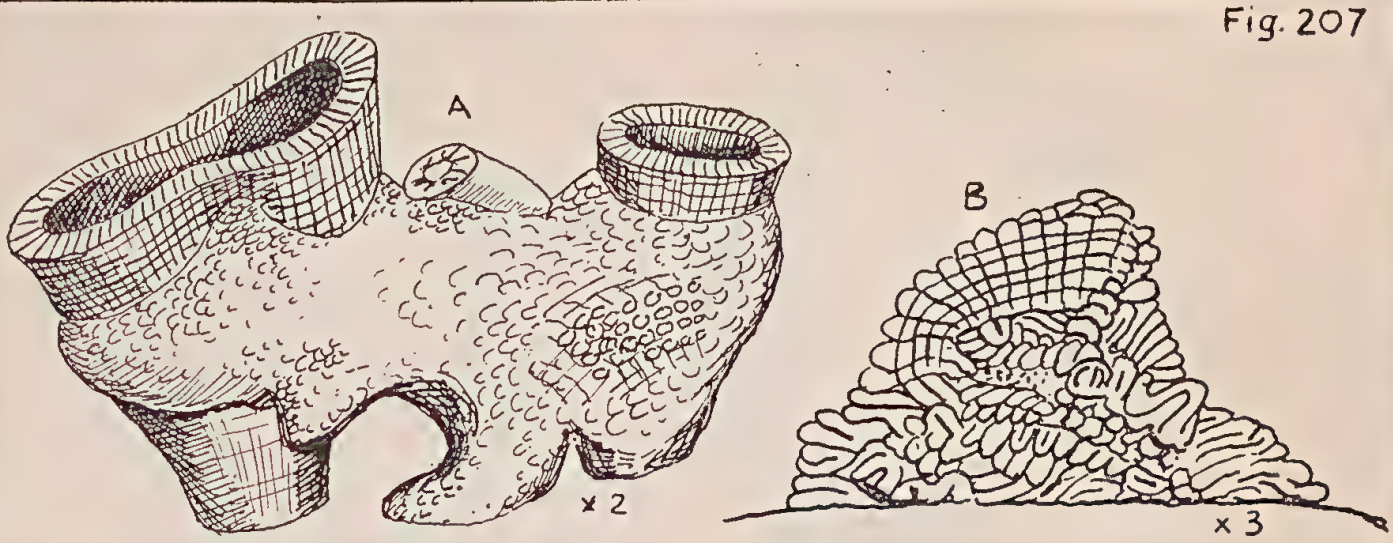
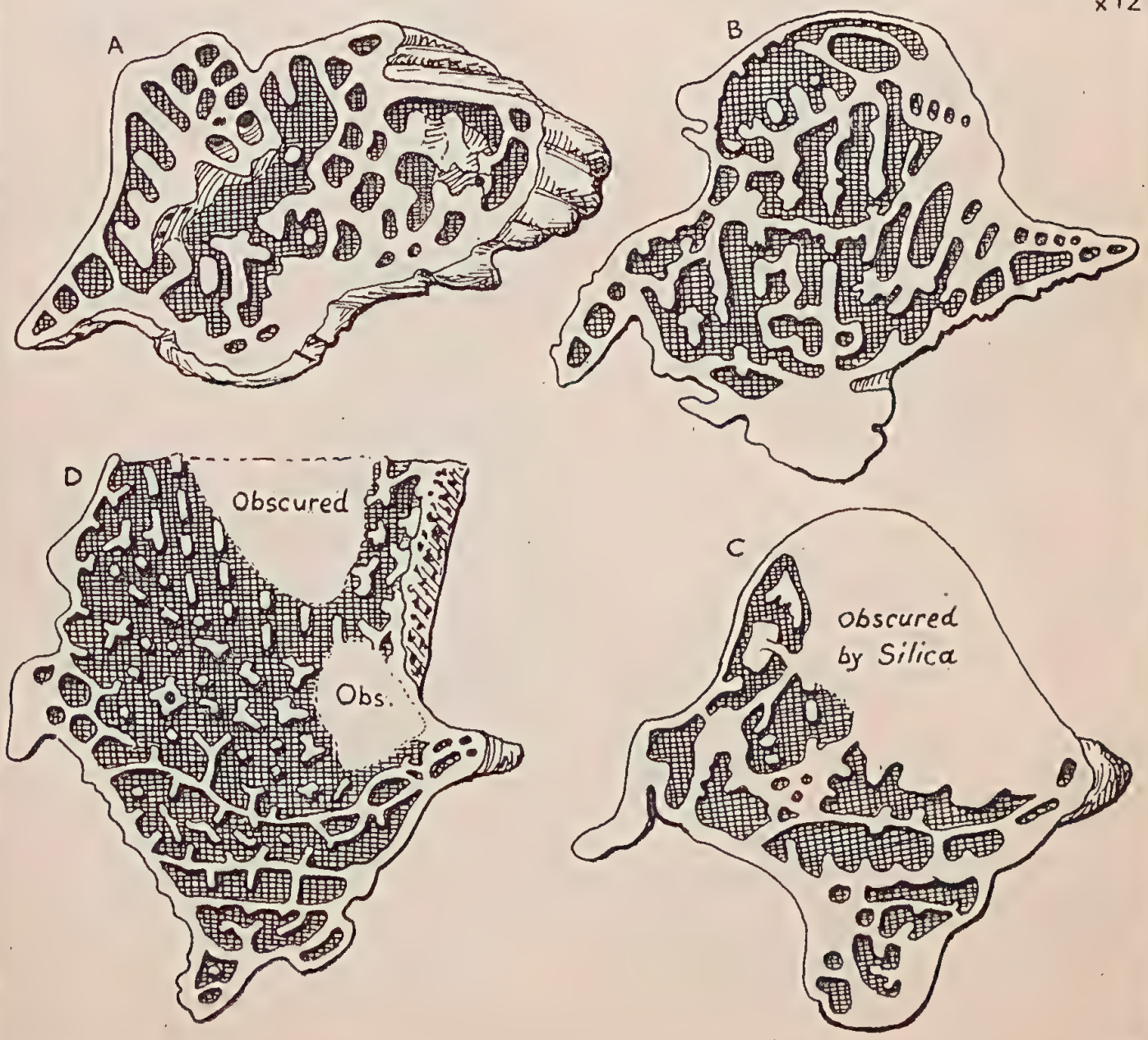
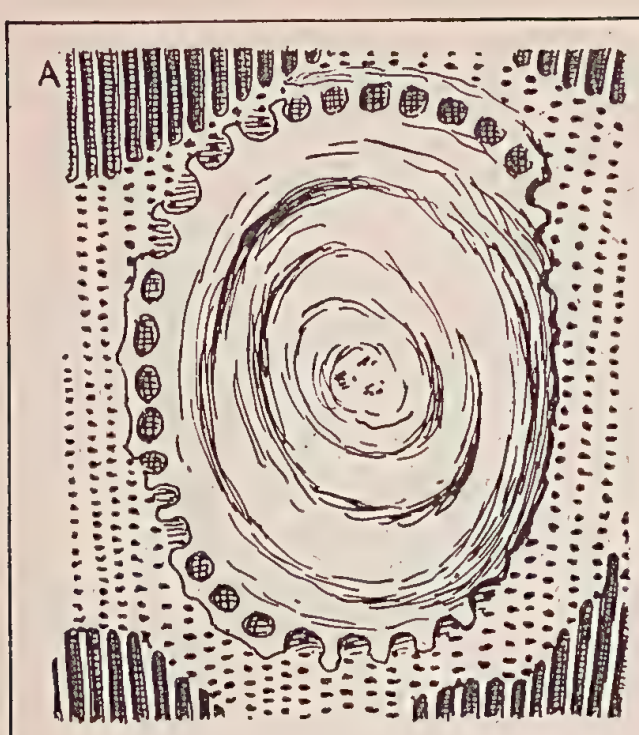


Fig. 208
x 12



207. *Labyrinthomorpha (after Vologdin).*

208. *c/f Exocyathus or Metaldetimorpha.*



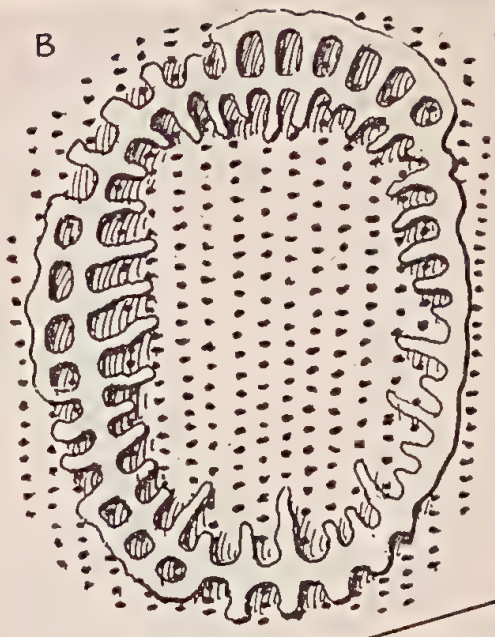


Fig. 209
×6

Fig. 211

Fig. 210

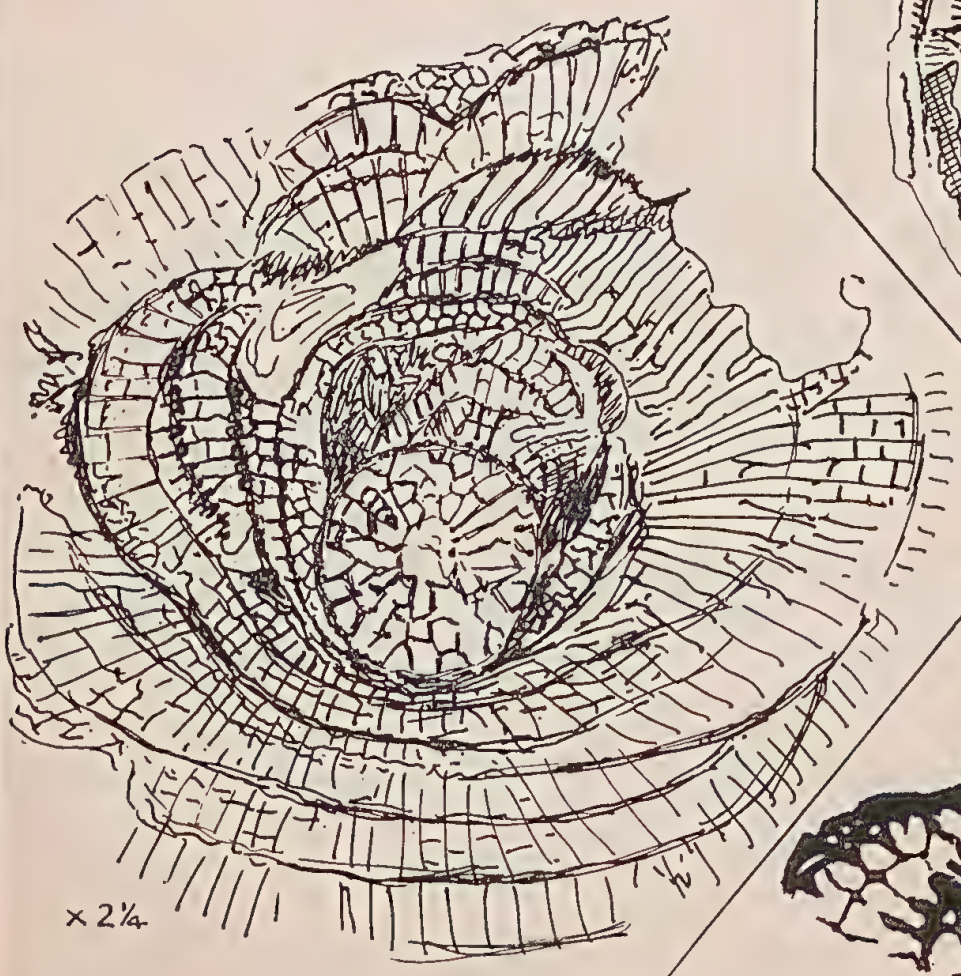
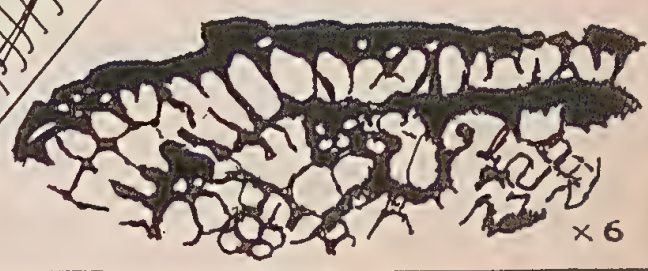


Fig. 212



209. *c/f Exocyathus or Metaldetimorpha.*

210. *"Archaeocyathus profundus" (after Bornemann).*

211. *"Calathium anstedi or crassum" (after Billings).*

212. *"Protopharetra polymorpha" (after Bornemann).*

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